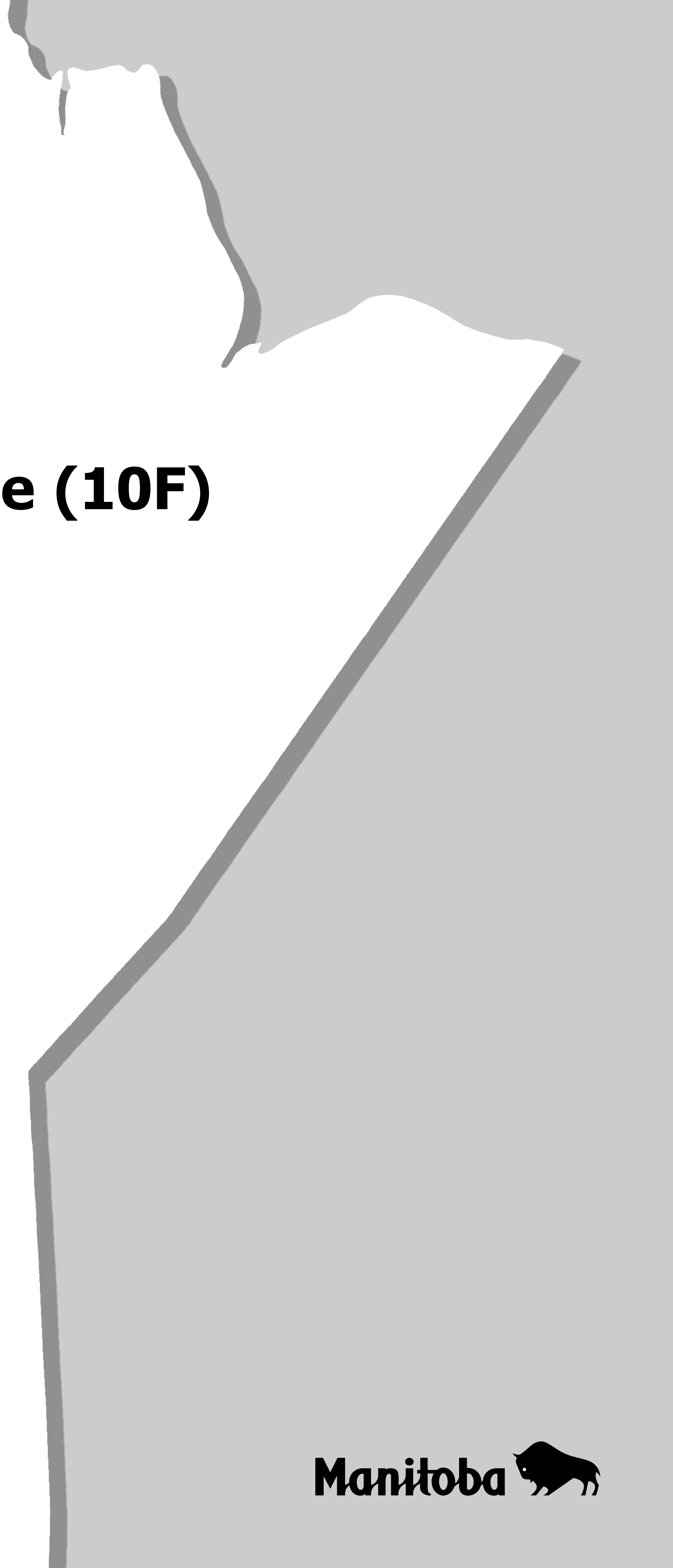
Grade 9 Science (10F)

A Course for
Independent Study



Manitoba

GRADE 9 SCIENCE (10F)

A Course for Independent Study

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Manitoba Education
Winnipeg, Manitoba, Canada

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Disponible en français.

Available in alternate formats upon request.

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Module 4: Exploring the Universe 1

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INTRODUCTION

Overview

Welcome to *Grade 9 Science: A Course for Independent Study*!

In this course, you will examine the very atoms that make up all matter on Earth, discover how electricity has been harnessed to operate machinery, uncover how our body tissues grow and regenerate, and explore the far-off stars and planets of our galaxy.

As a student enrolled in an independent study course, you have taken on a dual role—that of a student and a teacher. As a student, you are responsible for mastering the lessons and completing the learning activities and assignments. As a teacher, you are responsible for checking your work carefully, noting areas in which you need to improve and motivating yourself to succeed.

What Will You Learn in This Course?

In each lesson, you will read a few pages and then complete a learning activity and/or assignment. Some lessons will have hands-on experiments for you to perform, while others may require you to do some investigative research or observation work in the community.

The modules in this course are not cumulative; in fact, feel free to approach the modules in any order you prefer. Keep in mind that the astronomy module, "Exploring the Universe," will require you to observe planets and constellations in the night sky. You may wish to schedule this module for the fall and winter months when you will have the most nighttime hours at your disposal.

How Is This Course Organized?

The Grade 9 Science course consists of the following four modules:

- Module 1: Reproduction
- Module 2: Atoms and Elements
- Module 3: The Nature of Electricity
- Module 4: Exploring the Universe

Each module in this course consists of several lessons, which contain the following components:

- **Introduction:** Each lesson begins by outlining what you will be learning.
- **Lesson Focus:** Each lesson focuses on learning outcomes which are goals you should have accomplished by the end of the lesson as prescribed by Manitoba Education.
- **Lesson:** The main body of the lesson is made up of the content that you need to learn. It contains explanations, diagrams, and fully completed examples.
- **Summary:** Each lesson ends with a brief review of what you just learned.
- **Learning Activities:** Most lessons have a learning activity. These include questions that you should complete in order to help you practise or review what you have just learned. Once you have completed a learning activity, you should check your answers with the answer key provided at the end of the module.
- **Assignments:** Assignments are found at the end of lessons. In all, the assignments will be worth a total of 75 percent of your final mark. You will mail or email all of your completed assignments to your tutor/marker for assessment.

What Resources Will You Need for This Course?

You do not need a textbook for this course. All the content is provided directly within the course. You will, however, need access to a variety of resources.

You will require access to an email account if you plan to

- communicate with your tutor/marker by email
- use the learning management system (LMS) to submit your completed assignments.

The required resources for this course are identified on the following page.

Required Resources

- A learning partner should be available to help you to complete some learning activities (see page 7 for a further description of your learning partner). An adult should also be available to supervise certain assignments that involve hands-on experiments.
- Each module has a list of equipment required for completing its learning activities (LA) and assignments (A). Plan out the order in which you will complete each module and make a point of having your materials ready when you begin a new module.
- The supply list below identifies the items required for the hands-on experiments found in either Learning Activities (LA) or Assignments (A) for the whole course. In some circumstances you have a choice of experiments (e.g., in Module 2, Assignment 2.4; in Module 3, Assignment 3.2, Learning Activity 3.7, Learning Activity 3.12, and Learning Activity 3.13).

Item Required	Module 1	Module 2	Module 3	Module 4
masking tape	LA 1.14		LA 3.13, Option 2	
4 pennies	LA 1.14			
salt		A 2.4, Option 1		
water		A 2.4, Option 1		
teaspoon		A 2.4, Option 1		
glass tumbler		A 2.4, Option 1	LA 3.3	
stir stick		A 2.4, Option 1		
magnifying glass		A 2.4, Options 1 and 2		
1 effervescent tablet		A 2.4, Option 2		
scraping tool		A 2.4, Option 2		
candle		A 2.4, Option 3		
candle holder		A 2.4, Option 3		
matches		A 2.4, Option 3		
steel wool pad		A 2.4, Option 4		
thermometer		A 2.4, Option 4		
vinegar		A 2.4, Option 4		

continued

Item Required	Module 1	Module 2	Module 3	Module 4
airtight jar		A 2.4, Option 4		
small cup		A 2.4, Option 4		
plastic straw			LA 3.1, 3.3, 3.5 A 3.2, Option 1	
paper bits			LA 3.1, 3.5	
wool cloth/fabric			LA 3.1, 3.3, 3.5	
transparent tape (packing tape)			LA 3.1; 3.3; 3.12, Option 2; 3.13, Option 2 A 3.2, Options 1 and 2; A 3.5, Option 2	LA 4.2
15 cm of copper tubing (1 cm in diameter)			LA 3.3	
30 cm string			LA 3.3	
thread			LA 3.5 A 3.2, Option 1	
pith ball or piece of foam			LA 3.3	
foam cup			A 3.2, Options 1 and 2	
aluminum foil			A 3.2, Options 1 and 2	
soda can with pull tab			A 3.2, Option 2	
lemon			LA 3.7, Option 1	
copper wire			LA 3.7, Option 1	
neon bulb, ammeter, galvanometer, or multimeter			LA 3.7, Option 1	
iron nail, plus welding rods, wires, or other metals			LA 3.7, Option 1	
2 D cell batteries			LA 3.12, Option 2 LA 3.13, Option 2 A 3.5, Option 2	
2 small flashlight bulbs			LA 3.12, Option 2 LA 3.13, Option 2 A 3.5, Option 2	
insulated copper wire			LA 3.13, Option 2 A 3.5, Option 2	

continued

Item Required	Module 1	Module 2	Module 3	Module 4
light gauge wire			LA 3.12, Option 2	
thick corrugated cardboard				LA 4.2
scissors				LA 4.2
20 cm of thin string or coloured fishing line				LA 4.2
small weight (e.g., washer, nickel)				LA 4.2
large drinking straw at least .5 cm in diameter				LA 4.2
glue stick				LA 4.2
orienteering-type compass				LA 4.5, A 4.2
metre stick				LA 4.10
small protractor				LA 4.10, A 4.6
centimetre ruler				LA 4.10, A 4.6

- **A computer with Internet access:** Some lessons suggest website links as sources of information or for supplementary reference and reading. If you do not have Internet access, you will still be able to complete the course, but you will need to find different ways of accessing information.
  - Internet access is required to download *Crocodile Clips* software from www.yenka.com/en/Free_student_home_licences/, which is needed if you choose Option 1 of Learning Activities 3.7, 3.12, and/or 3.13 and/or Assignment 3.5.
  - In Module 3, Lesson 15, you will require a home hydro bill. If you do not have one, a sample Manitoba Hydro bill is available online at www.hydro.mb.ca/mybill/sample_bill.pdf.
  - Internet access is required to attain a simplified star chart or planisphere online for Assignment 4.2 and Learning Activity 4.5. Please contact your tutor/marker if you are unable to obtain one.

A note about Internet sites: All of the URLs listed in this course were working when this course was written, but, since Internet sites come and go, you might find that some of these sites are no longer active or appropriate. If that happens, you could use a search engine (e.g., www.google.ca) to find the information that you are looking for.

Optional Resources

Access to the following resources would be beneficial in completing this course:

- **A computer and word processing software:** Access to word processing software (e.g., Microsoft Word) would help you complete some assignments.
- **Resource people:** Access to local resource people, such as teachers, school counsellors, and librarians, would help you complete this course.
- **Photocopier/scanner:** With access to a photocopier/scanner, you could make a copy of your assignments before submitting them so that if your tutor/marker wants to discuss an assignment with you over the phone, each of you will have a copy. It would also allow you to continue studying or to complete further lessons while your original work is with the tutor/marker. Photocopying or scanning your assignments will also ensure that you keep a copy in case the originals are lost.

Who Can Help You with This Course?

Taking an independent study course is different from taking a course in a classroom. Instead of relying on the teacher to tell you to complete a learning activity or an assignment, you must tell yourself to be responsible for your learning and for meeting deadlines. There are, however, two people who can help you be successful in this course: your tutor/marker and your learning partner.

Your Tutor/Marker

Tutor/markers are experienced educators who tutor Independent Study Option (ISO) students and mark assignments and examinations. When you are having difficulty with something in this course, contact your tutor/marker, who is there to help you. Your tutor/marker's name and contact information were sent to you with this course. You can also obtain this information in the learning management system (LMS).

Your Learning Partner(s)

A learning partner is someone **you choose** who will help you learn. It may be someone who knows something about science, but it doesn't have to be. A learning partner could be someone else who is taking this course, a teacher, a parent or guardian, a sibling, a friend, or anybody else who can help you. Most importantly, a learning partner should be someone with whom you feel comfortable and who will support you as you work through this course.

Your learning partner can help you keep on schedule with your coursework, read the course with you, check your work, look at and respond to your learning activities, or help you make sense of assignments. You may even study for your examination(s) with your learning partner. If you and your learning partner are taking the same course, however, your assignment work should not be identical.

Plagiarism

Plagiarism is taking someone's ideas or words as if they are your own, without giving credit where credit is due. Some examples include the following:

- downloading material in whole or part from the Internet and submitting it as your own
- copying word-for-word from published or unpublished work
- paraphrasing, or using ideas from, published or unpublished work without giving credit

How can you avoid plagiarism?

1. Begin early because research takes time. In addition to the time needed to search for, evaluate, and read sources, you also need to remember to allow time to get help if you need it. Always document your sources immediately.
2. Incorporate information using quotations or paraphrases. A quotation uses exactly the same words and puts them in quotation marks. A paraphrase uses an author's idea, but expresses it in your own words—without quotation marks, since it is no longer a word-for-word quotation. And just changing a few words from the original does not count.
3. Discover how to use various citation styles like MLA to cite your sources.
4. Give credit where credit is due!

How Will You Know How You Are Learning?

You will know how well you are learning in this course by how well you complete the learning activities, assignments, and examinations.

Learning Activities

The learning activities in this course will help you to review and practise what you have learned in the lessons. You will not submit the completed learning activities to the Distance Learning Unit. Instead, you will complete the learning activities and compare your responses to those provided in the Learning Activity Answer Key found at the end of each module.

Make sure you complete the learning activities. Doing so will not only help you to practise what you have learned, but will also prepare you to complete your assignments and the examination successfully. Many of the questions on the examination will be similar to the questions in the learning activities. **Remember that you will not submit learning activities to the Distance Learning Unit**

Assignments

Lesson assignments are located throughout the modules and include questions similar to the questions in the learning activities of previous lessons. The assignments have space provided for you to write your answers on the question sheets. You need to show all your steps as you work out your solutions, and make sure your answers are clear (include units, where appropriate).

Once you have completed all the assignments in a module, you will submit them to the Distance Learning Unit for assessment. The assignments are worth a total of 75 percent of your final course mark. You must complete each assignment in order to receive a final mark in this course. You will mail or electronically submit these assignments to the Distance Learning Unit along with the appropriate cover sheet once you complete each module.

The tutor/marker will mark your assignments and return them to you. Remember to keep all marked assignments until you have finished the course so that you can use them to study for your examination.

Final Examination

The final examination is based on all four modules and is worth 25 percent of the final mark of the course. In order to do well on the final examination, you should review all of the work that you have completed from Modules 1 to 4, including all learning activities and assignments. You should also complete and check your answers for the Final Practice Examination.

Practice Examinations and Answer Keys

To help you succeed in your examination, you will have an opportunity to complete a Final Practice Examination. This examination, along with the answer key, is found in the learning management system (LMS). If you do not have access to the Internet, contact the Distance Learning Unit at 1-800-465-9915 to obtain a copy of the practice examination.

The practice examination is similar to the actual examination you will be writing. The answer key enables you to check your answers. This will give you the confidence you need to do well on your examination.

Requesting Your Examinations

You are responsible for making arrangements to have the examination sent to your proctor from the Distance Learning Unit. Please make arrangements before you finish Module 4 to write the final examination.

To write your examination, you need to make the following arrangements:

- **If you are attending school,** your examination will be sent to your school as soon as all the applicable assignments have been submitted. You should make arrangements with your school's ISO school facilitator to determine a date, time, and location to write the examination.
- **If you are not attending school,** check the Examination Request Form for options available to you. Examination Request Forms can be found on the Distance Learning Unit's website, or look for information in the learning management system (LMS). Two weeks before you are ready to write the examination, fill in the Examination Request Form and mail, fax, or email it to

  Distance Learning Unit
  500–555 Main Street
  PO Box 2020
  Winkler MB R6W 4B8
  Fax: 204-325-1719
  Toll-Free Telephone: 1-800-465-9915
  Email: distance.learning@gov.mb.ca

How Much Time Will You Need to Complete This Course?

Learning through independent study has several advantages over learning in the classroom. You are in charge of how you learn and you can choose how quickly you will complete the course. You can read as many lessons as you wish in a single session. You do not have to wait for your teacher or classmates.

From the date of your registration, you have a maximum of **12 months** to complete the course, but the pace at which you proceed is up to you. Read the following suggestions on how to pace yourself.

Chart A: Semester 1

If you want to start this course in September and complete it in January, you can follow the timeline suggested below.

Module	Completion Date
Module 1	End of September
Module 2	End of October
Module 3	Middle of November
Module 4	End of December
Final Examination	Middle of January

Chart B: Semester 2

If you want to start the course in February and complete it in May, you can follow the timeline suggested below.

Module	Completion Date
Module 1	End of February
Module 2	End of March
Module 3	Middle of April
Module 4	Beginning of May
Final Examination	Middle of May

Chart C: Full School Year (Not Semestered)

If you want to start the course in September and complete it in May, you can follow the timeline suggested below.

Module	Completion Date
Module 1	End of September
Module 2	End of November
Module 3	End of January
Module 4	End of March
Final Examination	Middle of May

Timelines

Do not wait until the last minute to complete your work, since your tutor/marker may not be available to mark it immediately. It may take a few weeks for your tutor/marker to assess your work and return it to you or your school.

Note

If you need this course to graduate this school year, all coursework must be received by the Distance Learning Unit on or before the first Friday in May, and all examinations must be received by the Distance Learning Unit on or before the last Friday in May. Any coursework or examinations received after these deadlines may not be processed in time for a June graduation. Assignments or examinations submitted after these recommended deadlines will be processed and marked as they are received.

When and How Will You Submit Completed Assignments?

When to Submit Assignments

While working on this course, you will submit completed assignments to the Distance Learning Unit four times. The following chart shows you exactly what assignment you will be submitting at the end of each module.

Submission of Assignments	
Submission	Assignments You Will Submit
1	**Module 1: Reproduction** Module 1 Cover Sheet Assignment 1.1: Dual Option Assignment Assignment 1.2: From Conception to Birth Assignment 1.3: Mutagens Investigation Assignment 1.4: Research into Genetics
2	**Module 2: Atoms and Elements** Module 2 Cover Sheet Assignment 2.1: Atomic Timeline Assignment 2.2: Subatomic Particles and the Bohr Model Assignment 2.3: Chemical Reactivity on the Periodic Table Assignment 2.4: Chemical and Physical Change Experiments
3	**Module 3: The Nature of Electricity** Module 3 Cover Sheet Assignment 3.1: Understanding Electricity Assignment 3.2: Create Your Own Electroscope Assignment 3.3: Producing Electricity Assignment 3.4: Circuits Review Assignment 3.5: Smple Circuits Lab Assignment 3.6: Electricity Project
4	**Module 4: Exploring the Universe** Module 4 Cover Sheet Assignment 4.1: Measuring Altitude Assignment 4.2: Locating Celestial Objects Using a System of Coordinates Assignment 4.3: Path of the Sun and the Moon Assignment 4.4: Monitoring the Retgrograde Motion of the Planet Mars Assignment 4.5: Life on Mars Assignment 4.6: Measuring in Space Assignment 4.7: Stars Assignment 4.8: Mars Colony Project

How to Submit Assignments

In this course, you have the choice of submitting your assignments either by mail or electronically.

- **Mail:** Each time you **mail** something, you must include the print version of the applicable Cover Sheet (found at the end of this Introduction). Complete the information at the top of each Cover Sheet before submitting it along with your assignments.
- **Electronic submission:** You do not need to include a cover sheet when submitting assignments electronically.

Submitting Your Assignments by Mail

If you choose to mail your completed assignments, please photocopy/scan all the materials first so that you will have a copy of your work in case your package goes missing. You will need to place the applicable module Cover Sheet and assignment(s) in an envelope, and address it to

Distance Learning Unit
500–555 Main Street
PO Box 2020
Winkler MB R6W 4B8

Your tutor/marker will mark your work and return it to you by mail.

Submitting Your Assignments Electronically

Assignment submission options vary by course. Sometimes assignments can be submitted electronically and sometimes they must be submitted by mail. Specific instructions on how to submit assignments were sent to you with this course. In addition, this information is available in the learning management system (LMS).

If you are submitting assignments electronically, make sure you have saved copies of them before you send them. That way, you can refer to your assignments when you discuss them with your tutor/marker. Also, if the original hand-in assignments are lost, you are able to resubmit them.

Your tutor/marker will mark your work and return it to you electronically.

The Distance Learning Unit does not provide technical support for hardware-related issues. If troubleshooting is required, consult a professional computer technician.

What Are the Guide Graphics For?

Guide graphics are used throughout this course to identify and guide you in specific tasks. Each graphic has a specific purpose, as described below:

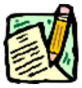
Lesson Focus/Specific Learning Outcomes (SLOs): Note that these SLOs will be addressed within the lesson.

Internet: Use the Internet, if you have access to it, to obtain more information. Internet access is optional for this course.

Learning Partner: Ask your learning partner to help you with this task.

Phone Your Tutor/Marker: Telephone your tutor/marker.

Learning Activity: Complete a learning activity. This will help you to review or practise what you have learned and to prepare for an assignment or an examination. You will not submit learning activities to the Distance Learning Unit. Instead, you will compare your responses to those provided in the Learning Activity Answer Key found at the end of the applicable module.



Assignment: Complete an assignment. You will submit your completed assignments to the Distance Learning Unit for assessment at the specified times.

Mail or Electronic Submission: Mail or electronically submit your completed assignments to the Distance Learning Unit.

Examination: Write your final examination at this time.

Note: Take note of and remember this important information or reminder.

Key Word: Note that a new important term is being explained.

Remember: If you have questions or need help at any point during this course, contact your tutor/marker or ask your learning partner for help.

Good luck with this course!

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Module 1 Cover Sheet

Please complete this sheet and place it on top of your assignments to assist in proper recording of your work. Submit the package to:

Drop-off/Courier Address

Distance Learning Unit
555 Main Street
Winkler MB R6W 1C4

Mailing Address

Distance Learning Unit
500–555 Main Street
PO Box 2020
Winkler MB R6W 4B8

Contact Information

Legal Name: ____________________ Preferred Name: ____________________

Phone: ____________________ Email: ____________________

Mailing Address: ____

City/Town: ______________________________ Postal Code: __________

Attending School: ☐ No ☐ Yes

School Name: ____

Has your contact information changed since you registered for this course? ☐ No ☐ Yes

Note: Please keep a copy of your assignments so that you can refer to them when you discuss them with your tutor/marker.

For Student Use	For Office Use Only	
Module 1 Assignments	**Attempt 1**	**Attempt 2**
Which of the following are completed and enclosed? Please check (✓) all applicable boxes below.	__________ Date Received	__________ Date Received
☐ Assignment 1.1: Dual Option Assignment	________ /30	________ /30
☐ Assignment 1.2: From Conception to Birth	________ /40	________ /40
☐ Assignment 1.3: Mutagens Investigation	________ /24	________ /24
☐ Assignment 1.4: Research into Genetics	________ /14	________ /14
	Total: ____ **/108**	**Total:** ____ **/108**
For Tutor/Marker Use		
Remarks:		

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Module 2 Cover Sheet

Please complete this sheet and place it on top of your assignments to assist in proper recording of your work. Submit the package to:

Drop-off/Courier Address

Distance Learning Unit
555 Main Street
Winkler MB R6W 1C4

Mailing Address

Distance Learning Unit
500–555 Main Street
PO Box 2020
Winkler MB R6W 4B8

Contact Information

Legal Name: ____________________ Preferred Name: ____________________

Phone: ____________________ Email: ____________________

Mailing Address: ____

City/Town: ____________________ Postal Code: __________

Attending School: ☐ No ☐ Yes

School Name: ____

Has your contact information changed since you registered for this course? ☐ No ☐ Yes

Note: Please keep a copy of your assignments so that you can refer to them when you discuss them with your tutor/marker.

For Student Use	For Office Use Only	
Module 2 Assignments	**Attempt 1**	**Attempt 2**
Which of the following are completed and enclosed? Please check (✓) all applicable boxes below.	________ Date Received	________ Date Received
☐ Assignment 2.1: Atomic Timeline	______ /19	______ /19
☐ Assignment 2.2: Subatomic Particles and the Bohr Model	______ /34	______ /34
☐ Assignment 2.3: Chemical Reactivity on the Periodic Table	______ /41	______ /41
☐ Assignment 2.4: Chemical and Physical Change Experiments	______ /16	______ /16
	Total: ____ **/110**	**Total:** ____ **/110**

For Tutor/Marker Use
Remarks:

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Module 3 Cover Sheet

Please complete this sheet and place it on top of your assignments to assist in proper recording of your work. Submit the package to:

Drop-off/Courier Address

Distance Learning Unit
555 Main Street
Winkler MB R6W 1C4

Mailing Address

Distance Learning Unit
500–555 Main Street
PO Box 2020
Winkler MB R6W 4B8

Contact Information

Legal Name: ____________________ Preferred Name: ____________________

Phone: ____________________ Email: ____________________

Mailing Address: ____

City/Town: ______________________________ Postal Code: ____________

Attending School: ☐ No ☐ Yes

School Name: ____

Has your contact information changed since you registered for this course? ☐ No ☐ Yes

Note: Please keep a copy of your assignments so that you can refer to them when you discuss them with your tutor/marker.

For Student Use	For Office Use Only	
Module 3 Assignments Which of the following are completed and enclosed? Please check (✓) all applicable boxes below.	**Attempt 1** __________ Date Received	**Attempt 2** __________ Date Received
☐ Assignment 3.1: Understanding Electricity	______ /12	______ /12
☐ Assignment 3.2: Create Your Own Electroscope	______ /22	______ /22
☐ Assignment 3.3: Producing Electricity	______ /27	______ /27
☐ Assignment 3.4: Circuits Review	______ /23	______ /23
☐ Assignment 3.5: Simple Circuits Lab	______ /28	______ /28
☐ Assignment 3.6: Electricity Project	______ /15	______ /15
	Total: ____ **/127**	**Total:** ____ **/127**

For Tutor/Marker Use
Remarks:

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Module 4 Cover Sheet

Please complete this sheet and place it on top of your assignments to assist in proper recording of your work. Submit the package to:

Drop-off/Courier Address

Distance Learning Unit
555 Main Street
Winkler MB R6W 1C4

Mailing Address

Distance Learning Unit
500–555 Main Street
PO Box 2020
Winkler MB R6W 4B8

Contact Information

Legal Name: ______________________ Preferred Name: ______________________

Phone: ______________________ Email: ______________________

Mailing Address: ____

City/Town: ______________________________ Postal Code: ____________

Attending School: ☐ No ☐ Yes

School Name: ____

Has your contact information changed since you registered for this course? ☐ No ☐ Yes

Note: Please keep a copy of your assignments so that you can refer to them when you discuss them with your tutor/marker.

For Student Use	For Office Use Only	
Module 4 Assignments Which of the following are completed and enclosed? Please check (✓) all applicable boxes below.	**Attempt 1** __________ Date Received	**Attempt 2** __________ Date Received
☐ Assignment 4.1: Measuring Altitude	_______ /8	_______ /8
☐ Assignment 4.2: Locating Celestial Objects Using a System of Coordinates	_______ /14	_______ /14
☐ Assignment 4.3: Path of the Sun and the Moon	_______ /23	_______ /23
☐ Assignment 4.4: Monitoring the Retrograde Motion of the Planet Mars	_______ /11	_______ /11
☐ Assignment 4.5: Life on Mars	_______ /10	_______ /10
☐ Assignment 4.6: Measuring in Space	_______ /10	_______ /10

continued

GRADE 9 SCIENCE (10F)

Module 4 Cover Sheet *(continued)*

Please complete this sheet and place it on top of your assignments to assist in proper recording of your work. Submit the package to:

Drop-off/Courier Address
Distance Learning Unit
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Winkler MB R6W 1C4

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Has your contact information changed since you registered for this course? ☐ No ☐ Yes

Note: Please keep a copy of your assignments so that you can refer to them when you discuss them with your tutor/marker.

For Student Use	For Office Use Only	
Module 4 Assignments *(continued)* Which of the following are completed and enclosed? Please check (✓) all applicable boxes below.	**Attempt 1**	**Attempt 2**
	______________ Date Received	______________ Date Received
☐ Assignment 4.7: Stars	________ /20	________ /20
☐ Assignment 4.8: Mars Colony Project	________ /12	________ /12
	Total: ____ **/108**	**Total:** ____ **/108**
For Tutor/Marker Use		
Remarks:		

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Grade 9 Science Supply List

- A learning partner is recommended to assist and supervise the learning activities and assignments that involve hands-on experiments.
- Each module has a list of equipment required for completing the learning activities (L.A.) and assignments (A).
- The supply list below identifies the items required for the hands-on experiments found in either Learning Activities (L.A.) or Assignments (A) for the whole course. In some circumstances you have a choice of experiments e.g. Module 2 - Assignment 2.4, Module 3 - Assignment 3.2, Learning Activities 3.7 and 3.12 and 3.13.
- Many of the experiments in Module 3 can be done using the Crocodile Clips software instead of the hands-on experiments.

Item Required	Module 1	Module 2	Module 3	Module 4
Masking tape	L.A. 1.14		LA 3.13 Option 2	
4 pennies	L.A. 1.14			
Salt		A 2.4 Option 1		
Water		A 2.4 Option 1		
Teaspoon		A 2.4 Option 1		
Glass tumbler		A 2.4 Option 1	LA 3.3	
Stir stick		A 2.4 Option 1		
Magnifying glass		A 2.4 Option 1 and 2		
1 effervescent tablet		A 2.4 Option 2		
Scraping tool		A 2.4 Option 2		
Candle		A 2.4 Option 3		
Candle holder		A 2.4 Option 3		
Matches		A 2.4 Option 3		
Steel wool pad		A 2.4 Option 4		
Thermometer		A 2.4 Option 4		
Vinegar		A 2.4 Option 4		
Airtight jar		A 2.4 Option 4		
Small cup		A 2.4 Option 4		
Plastic straw			LA 3.1, 3.3, 3.5 A 3.2 Option 1	
Paper bits			LA 3.1, 3.5	
Wool cloth/fabric			LA 3.1, 3.3, 3.5	
Transparent tape (packing tape)			LA 3.1, 3.3, 3.12, 3.13 Option 2, A 3.2 Options 1 and 2, A 3.5 Option 2	LA 4.2
15 cm. copper tubing (1 cm in diameter)			LA 3.3	
30 cm string			LA 3.3	
thread			LA 3.5, A 3.2 Option 1	
Pith ball or piece of foam			LA 3.3	
Foam cup			A 3.2 Options 1 and 2	
Aluminum foil			A 3.2 Options 1 and 2	
Soda can with pull tab			A 3.2 Option 2	
Lemon			LA 3.7 Option 1	
Copper wire			LA 3.7 Option 1	

Neon bulb, ammeter, galvanometer or multimeter			LA 3.7 Option 1	
Iron nail plus welding rods or wires or other metals			LA 3.7 Option 1	
2 D cell batteries			LA 3.12 and 3.13 Option 2 A 3.5	
2 Small flashlight bulbs			LA 3.12 and 3.13 Option 2 A 3.5	
Insulted copper wire			A 3.5 Option 2 LA 3.13 Option 2	
Light gauge wire			LA 3.12 Option 2,	
Thick corrugated cardboard				LA 4.2
Scissors				LA 4.2
20 cm of thin string or coloured fishing line				LA 4.2
Small weight (e.g. washer, nickel)				LA 4.2
Large drinking straw at least .5 cm in diameter				LA 4.2
Glue stick				LA 4.2
Orienteering type compass				A 4.2, LA 4.5
Metre stick				LA 4.10
Small protractor				LA 4.10, A 4.6
Centimetre ruler				LA 4.10, A 4.6

Grade 9 Science (10F)

Module 1

Reproduction

This module contains the following:

MODULE 1
REPRODUCTION

Introduction

When you think about how a plant begins to grow, or how your baby brother came to be, you are thinking about reproduction. There are different types of reproduction used by different species. It is difficult to really understand how the reproductive cycles work, since it all begins in the cells of the organism.

You first began learning about cells and systems in Grade 8. You will carry on this work with this module. You may want to go back to your notes from Grade 8 Science to refresh your memory.

In this module, you will be using your understanding about cells and applying it to the reproduction of cells. You will learn about the reproductive system, conception through birth, and inheritance of traits.

You will need the following materials to complete this module:

- masking tape
- four pennies

You will notice that some of the lessons are accompanied by learning activities and assignments for you to complete. Complete the learning activities to help you learn about the information from the module and check the answer key in order to assess your understanding. Complete the assignments and submit them to the Distance Learning Unit according to the instructions found in the Introduction.

Learning Activities

There are several learning activities placed throughout this module, which will help you practise using the information you will learn. The answer keys for each of these learning activities are found in Module 1 Learning Activity Answer Key. Check the answer key carefully and make corrections to your work.

A **computer with Internet access** would be beneficial throughout the course. Additional support materials for the course are provided on websites that are listed. All of the URLs listed in this course were working when this course was written, but, since Internet sites come and go, you might find that some of these sites are no longer active or appropriate. If that happens, you could use a search engine (e.g., www.google.ca) to find the information that you are looking for.

Assignments in Module 1

When you complete Module 1, you will submit your Module 1 assignments, to the Distance Learning Unit either by mail or electronically through the learning management system (LMS). The staff will forward your work to your tutor/marker.

Lesson	Assignment Number	Assignment Title
6	Assignment 1.1	Dual Option Assignment
9	Assignment 1.2	From Conception to Birth
14	Assignment 1.3	Mutagens Investigation
16	Assignment 1.4	Research into Genetics

LESSON 1: INTRODUCTION TO THE CELL

Lesson Focus

After completing this lesson, you will be able to

- ☐ list the three main parts of plant and animal cells
- ☐ describe the function of the cell membrane
- ☐ describe the function of cell organelles

Key Words

- cell membrane
- nucleus
- cytoplasm
- organelles
- cellulose
- DNA
- genes
- nuclear envelope
- nucleoplasm
- chromosomes
- nucleolus
- ribosomes
- Golgi body
- lysosomes

Introduction

You have already learned about the structure of the cell. This section will serve as a review.

The cell is the basic unit of life. The individual cell performs the same life functions as a whole organism.

In fact, some organisms are made of only one cell. Every cell goes about the functions of

- using food for energy
- getting rid of waste
- reproducing itself
- creating material for growth and repair

In this lesson, you will learn about the cell structures that allow these functions to take place.

Basic Building Blocks

Cells are the basic building blocks of all life. Some organisms are composed of a single cell whereas others contain millions of cells.

A typical cell is made of three main parts.

- A **cell membrane** surrounds the cell. This membrane has small openings that provide places where the cell has contact with the environment outside.
- The **nucleus** directs the activities of the cell.
- The **cytoplasm** is a thick fluid inside the cell that, with the nucleus, makes up its total contents. The cytoplasm in turn is filled with **organelles** (little organs) that perform cell activities.

These common elements are found in most cells. Cells exist in many different shapes, however, and have many different functions.

The diagrams that follow show the structures present in plant and animal cells. Can you see any differences between the two diagrams?

Figure 1.1 **Plant Cell**

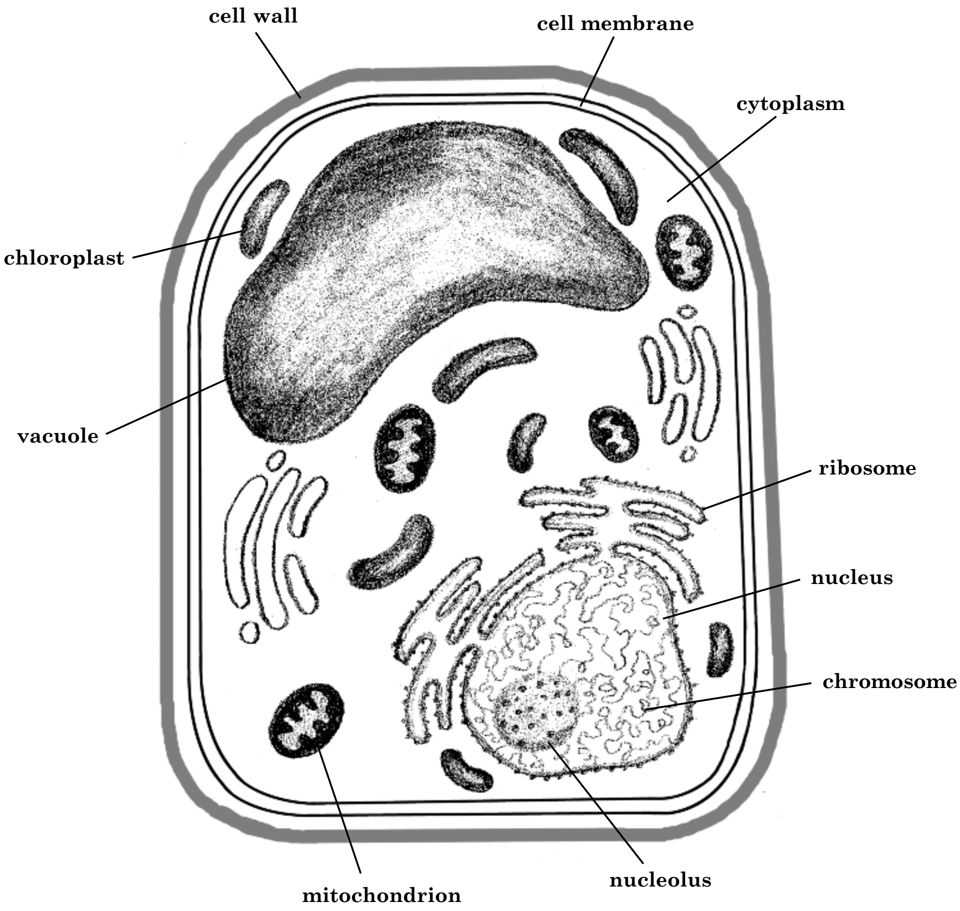
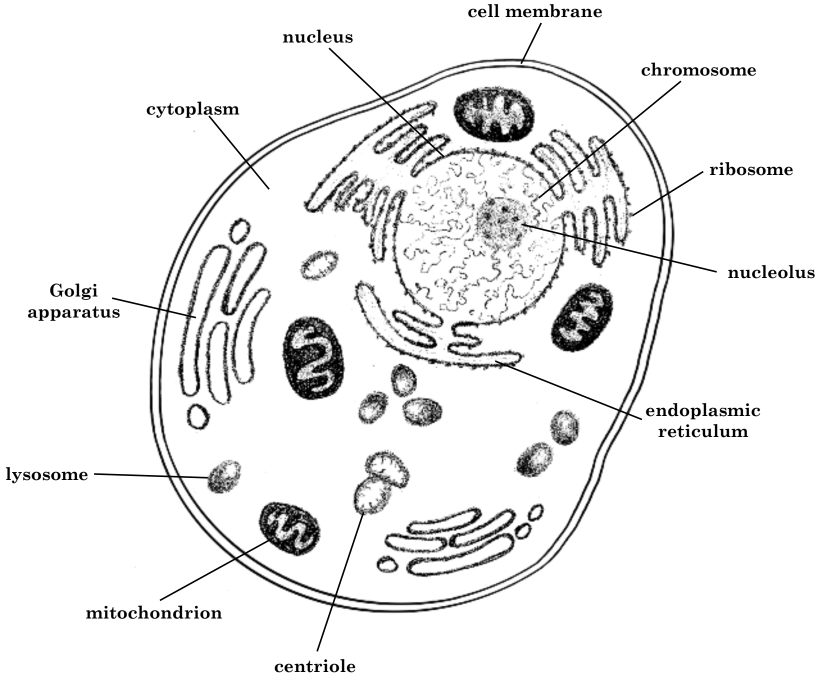


Figure 1.2 ***Animal Cell***



Plant and animal cells have many similar parts. Plant cells, however, have chloroplasts and cell walls. Animal cells do not have these features.

The previous cell drawings contain the standard parts of the two cell types. When looking at cells through a microscope, they will not be identical to the drawings. The parts in the drawing have been clarified and are easy to see and identify. Structures in real cells are harder to see. Some structures can only be seen with an electron microscope.

The organelles help the cell perform life functions including taking in food for energy and growth, eliminating waste, and adjusting to the environment.

Cell Membrane

The cell membrane is the thin, flexible material that surrounds the contents of the cell and allows it to make contact with its surroundings. The cell membrane consists of two layers of fat, with proteins located throughout the fat layers. The cell is able to control what substances pass through the membrane, allowing it to keep materials that are necessary for growth and survival, while eliminating materials that are harmful.

The cell membrane is considered to be selectively permeable; that is, it lets some materials pass through but not others. A cell wall found in plant cells but not in animal cells is composed of a non-living material called **cellulose**. The cellulose is quite rigid and supports the shape of the plant cells. Cell walls allow the passage of all materials and are considered to be permeable.

Parts of the Cell

A cell can be an independent unit or it can be part of a system that has a specific function in a more complex organism. In this lesson, you will first study the nucleus and various organelles, all of which have specific functions within the cell.

Nucleus

The nucleus is the largest of the cell organelles and acts as the cell's command centre.

The nucleus uses **DNA** (deoxyribonucleic acid) to command the activities of the cell. DNA is located in the nucleus and is used when a cell reproduces itself. DNA also builds proteins which allow the cell to adjust according to its surroundings. Packages of DNA are called **genes**.

The three parts to a nucleus are:

1. **Nuclear Envelope**

   The **nuclear envelope** is similar to the cell membrane except it covers the nucleus. It contains many selectively permeable pores that allow only certain proteins to pass through into the nucleus. The fluid material inside the nucleus is called the **nucleoplasm**.

2. **Chromosomes**

   Chromosomes contain all the information the cell needs to reproduce itself and produce proteins. Chromosomes are made of genes. Chromosomes replicate themselves prior to cell reproduction.

   Most cells are able to reproduce. A notable exception is red blood cells. Red blood cells are without a nucleus and are the only cells that can survive for any length of time without a nucleus. Their survival time is about two months.

3. **Nucleolus**

   There are several nucleoli in the nucleoplasm. These structures are not fully understood. Some scientists feel they are responsible for producing some proteins and **ribosomes** that pass out through the nuclear membrane into the cytoplasm.

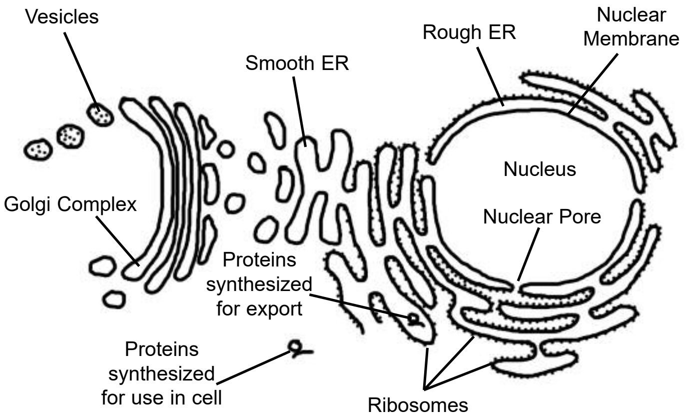
Cell Organelles

Cell organelles are located in the cytoplasm of the cell.

Endoplasmic Reticulum

The endoplasmic reticulum (ER) is responsible for moving proteins throughout the cell. It is a series of tubes and flattened sacs that connect to the nuclear envelope. Some of the ER is smooth and some is rough and dotted with ribosomes. Ribosomes are produced by the nucleus and settle onto the rough ER in order to build proteins.

Figure 1.3 ***Golgi Body***



Golgi Body

The **Golgi body** is responsible for the packaging and storage of proteins transported by the endoplasmic reticulum. The Golgi body looks like a series of folds, one on top of the other (see Figure 1.3 above). It is both structurally and functionally connected to the nucleus and the endoplasmic reticulum.

The Golgi body wraps the protein in packages. These packages are stored until needed or transported out of the cell if not needed. The Golgi body also packages certain enzymes into separate organelles called **lysosomes**.

Learning Activity 1.1

1. Describe the path of a protein molecule from the place where they are produced to the place where they are used in the cytoplasm.
2. If the endoplasmic reticulum is the transportation system, then the Golgi complex is the warehousing and packaging system. Explain this statement.
3. What part of the nucleus replicates itself as part of the reproductive process?
4. Why is the packaging of proteins in the Golgi complex an important part of the cell's function?

Check the answer key.

Summary

When viewing cells under a simple microscope, the nucleus can easily be seen as a dark spot in the cell. The nucleus is held together by the nuclear envelope. Within the nucleus there are other structures: the chromosomes, which contain all the information the cell needs to reproduce itself, and the nucleolus, which is not fully understood. Be careful not to confuse the nucleus with the nucleolus.

Other important organelles are the endoplasmic reticulum, which is responsible for protein manufacturing, and the Golgi body, which packages and stores protein.

Notes

LESSON 2: CELL DIVISION

Lesson Focus

After completing this lesson, you will be able to

- ☐ illustrate and explain cell division by mitosis in plants and animals
- ☐ place pictures of cells in various stages of cell division in the correct order
- ☐ list the differences and similarities between cell division in plants and animals
- ☐ draw diagrams explaining the events of cell division

Key Words

- reproduction
- cell cycle
- cell division phase
- mitosis
- cytokinesis
- interphase
- double stranded
- spindle fibres

Online Resources

The following websites provide information about cell division.

This is a good resource on mitosis.

- About.com
  http://biology.about.com/library/blmitosis.htm?once=true&

Choose the link to cell biology.

- The University of Arizona
  http://www.biology.arizona.edu/default.html

There are many sites relating to mitosis.

Introduction

You have spent some time reviewing cell structure in the last lesson. You are starting a new topic called **reproduction**. Reproduction is an important function for all living organisms for several reasons.

- **Healing and Tissue Repair**

  We would live in constant fear of cutting ourselves if there were no healing process. Instead, a cut quickly disappears as the cells in our body reproduce and replace the part that has been damaged. Some animals will even replace a lost limb. Our bodies are constantly replacing cells that have completed their life cycle. Skin cells are rubbed off and replaced; cells inside our body are similarly replaced as they wear out or are damaged.

  There are many questions about reproduction of cells in our bodies. How do they know when to begin a repair job? Why do some cells reproduce at a much higher rate than others? Why can some animals regenerate a limb?

  Whatever the answers to the questions are, we do know that reproduction of cells is an important part of general upkeep and repair of our bodies.

- **Growth**

  Growth of an organism is an important part of life. In order for growth to take place, cell division must occur.

  It might seem more efficient for growth to take place by keeping the same number of cells and having the cells increase in size. Why does your body increase in size by increasing the number of cells rather than the size of cells?

First, if cells were to increase in size, it would become difficult for the cell to receive nutrients and remove waste. Remember: substances can only enter and exit a cell through the cell membrane. The larger the cell, the harder it would need to work to move substances from its centre to its membrane and vice versa.

Secondly, the distance from the nucleus to all parts of the cytoplasm becomes larger, making it difficult for the nucleus to monitor and control the activities of the cell.

The cell size must be kept small for its efficient operation. Cell growth can only take place by increasing the number of cells.

- **Reproduction of the Organism**

  In order for life to continue, an organism must reproduce itself. Reproduction takes place from the simplest to the most complex of organisms in ways that we will explore in the lessons to come.

Cell Cycle

All cells come from pre-existing cells. Any new cell must come from another cell through a process of reproduction. Cells needed for repair, growth, or the maintenance of a species must use cell division.

Cells live through a sequence of steps called the **cell cycle**.

The cell cycle consists of a sequence of events that includes.

- cell division phase, which is a small part of the cell cycle that consists of **mitosis** and **cytokinesis**
- **interphase**, which is made up of the following three phases:
  - *rapid growth*

    The cell takes in sugars and proteins for growth and repair.
  - *duplication of chromosomes*

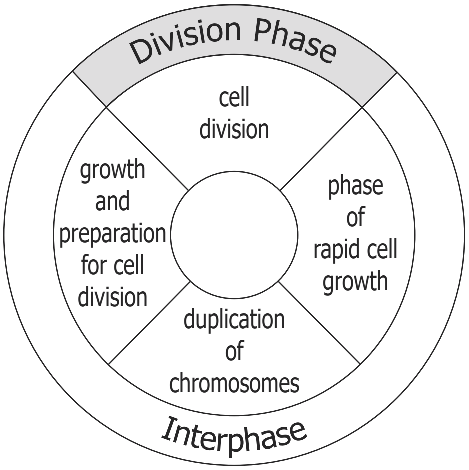
    The cell prepares for division by duplicating chromosomes in the nucleus. Duplication of genetic material must take place before cell division.
  - *growth and preparation for cell division*

    After chromosome duplication, there is another time of cell growth and preparation for cell division.

The cell cycle is shown in visual form below.

The circle represents the life of the cell. The division phase is a part of the cell cycle, but interphase occupies the larger portion of the cell cycle. Interphase can occupy a longer or shorter part of the cell cycle, depending on the type of cell.

Figure 1.4 **Cell Cycle**



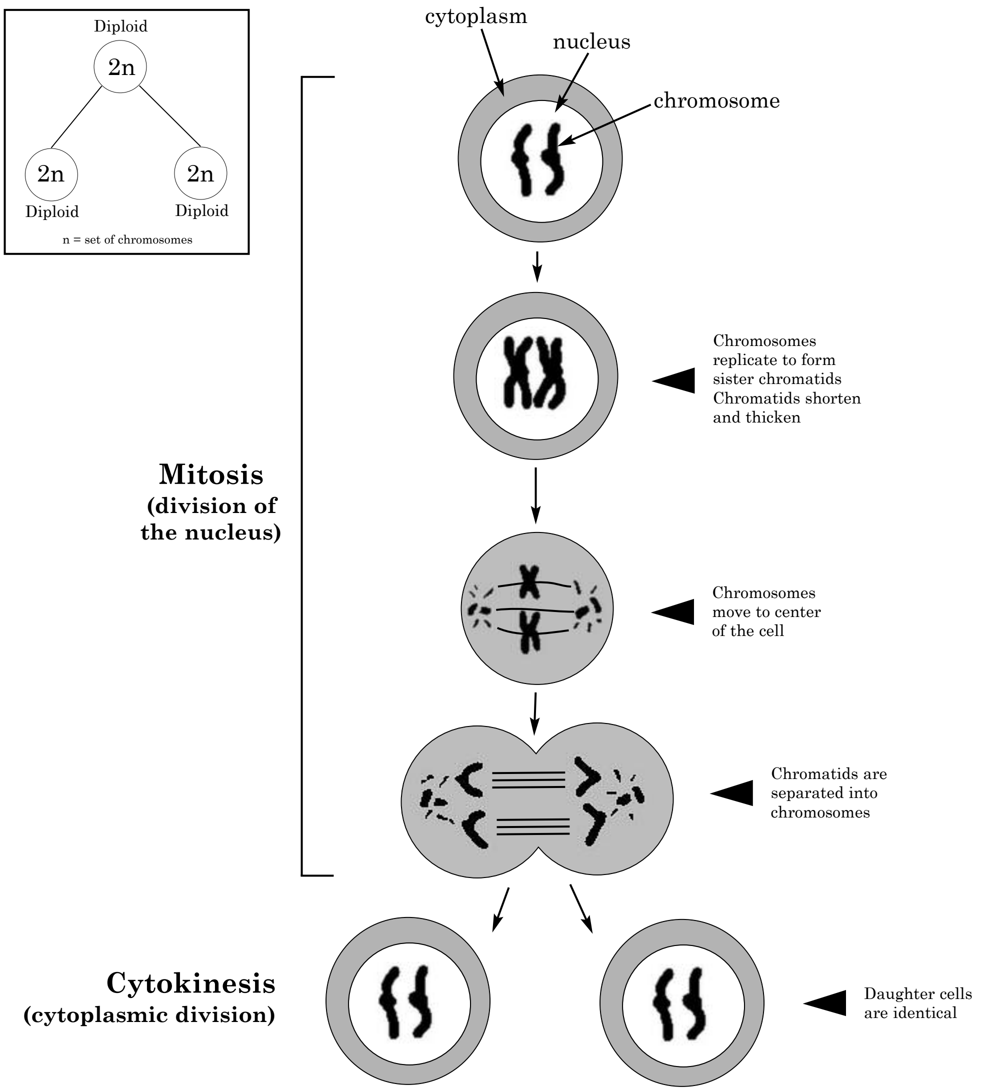
Cell Division

There are two parts to cell division.

- **Mitosis**
  - The division of the nucleus in such a way that both cells have a complete set of chromosomes is called mitosis.
  - Mitosis is responsible for the division of non-sex cells, which we call body cells.
- **Cytokinesis**
  - Cell division is complete when the cytoplasm is shared between the two cells resulting from the division. The process of sharing cytoplasm is called cytokinesis.
  - Cytokinesis is different in plant and animal cells. In animal cells, the cell membrane comes together in the middle of the cell and two new cells are formed. In plants, a new cell wall grows down the middle of the cell, producing two new plant cells.

    The two daughter cells will enter the interphase where they grow, producing more cytoplasm and becoming the size of the parent.

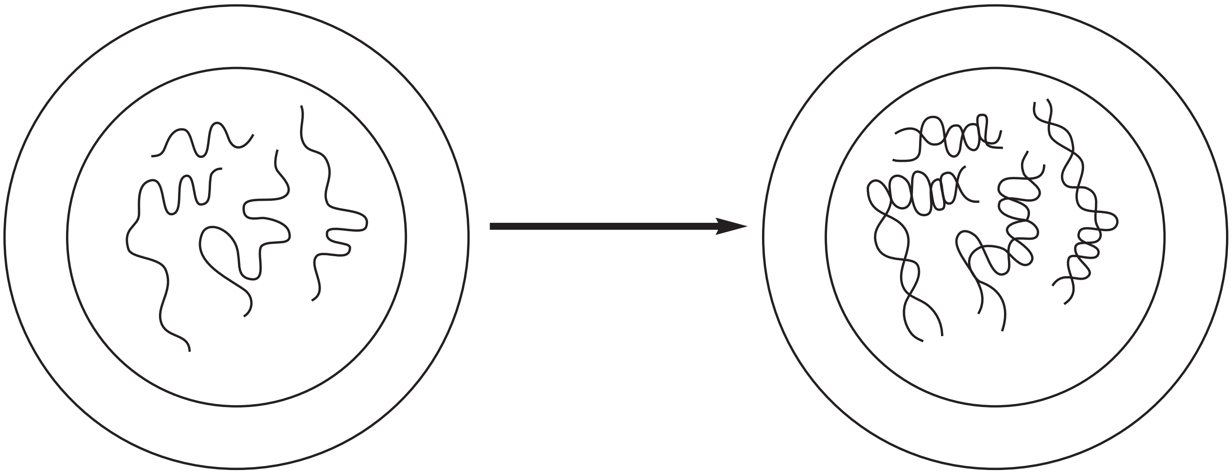
Figure 1.5 **Phases of Cell Division**



Although it is critical for you to understand the following stages of mitosis as a continuous and dynamic cycle, it is not necessary for you to memorize the names of each stage.

Interphase

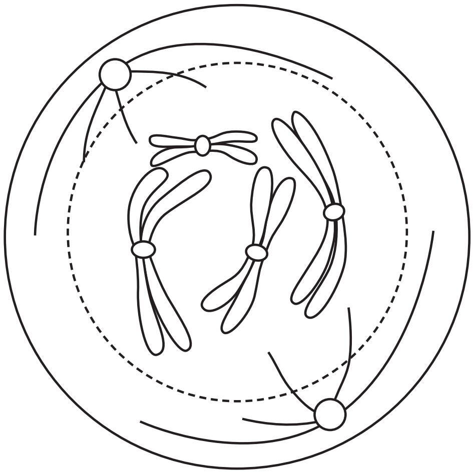
The nucleus makes a copy of the cell's genetic material so there are two complete sets of DNA. DNA (deoxyribonucleic acid) is the cell's genetic material that gives the cell whatever information it needs about its inherited characteristics.



1. **Prophase**

   The strands of DNA coil up to form rope-like structures called chromosomes. Remember that the DNA has been copied, so there is a duplicate of each chromosome present. Each duplicate is attached to the original, so we say that the chromosomes are **double-stranded**. During prophase, the nuclear envelope begins to dissolve and disappear. In animal cells, **spindle fibres** begin to form and stretch across the cell.

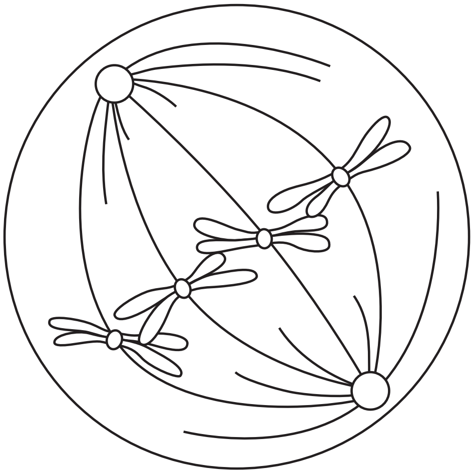
Figure 1.6 **Prophase**



2. **Metaphase**

   The spindle fibres tug the double-stranded chromosomes into a line across the middle of the cell.

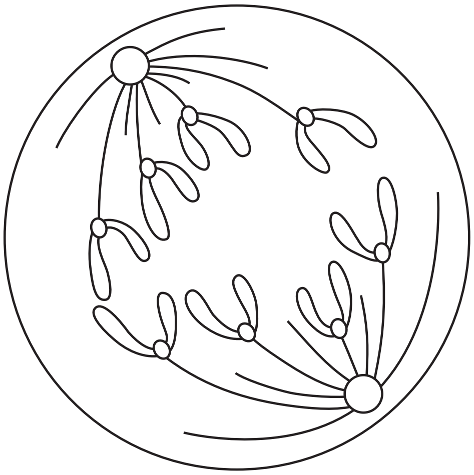
Figure 1.7 **Metaphase**



3. **Anaphase**

   The spindle fibres shorten, pulling the centromere apart, causing the chromosomes to move to opposite poles of the cell.

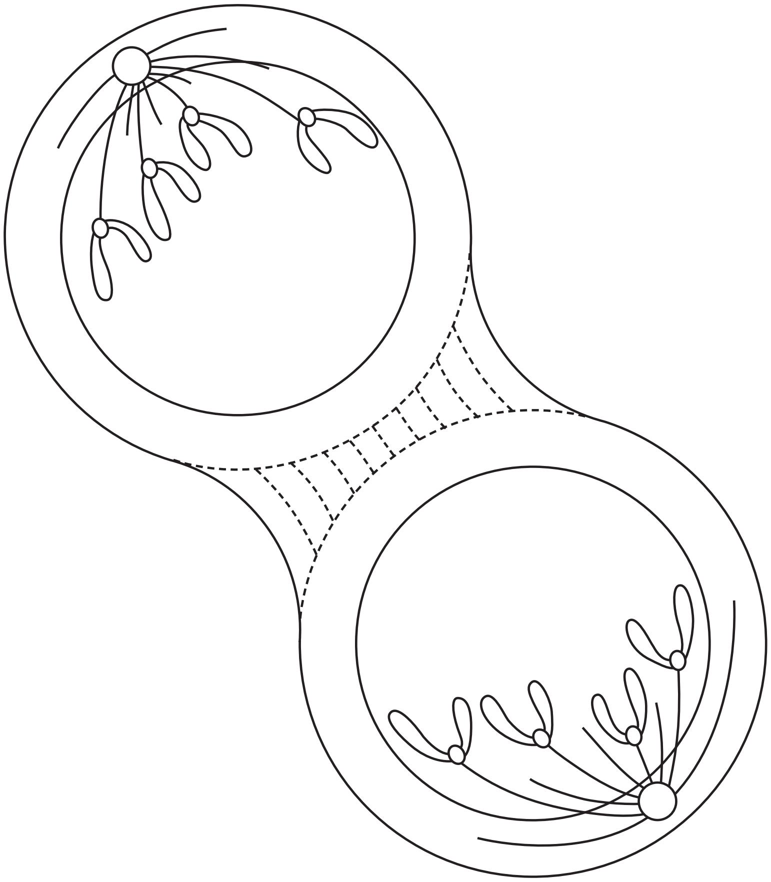
Figure 1.8 **Anaphase**



4. **Telophase**

   This is the final phase of mitosis. The chromosomes are located at opposite ends of the cell. The spindle fibres begin to disappear and a nuclear membrane forms around each new set of chromosomes. Chromosomes begin to uncoil and form strands of DNA. Cytokinesis begins.

Figure 1.9 **Telophase**



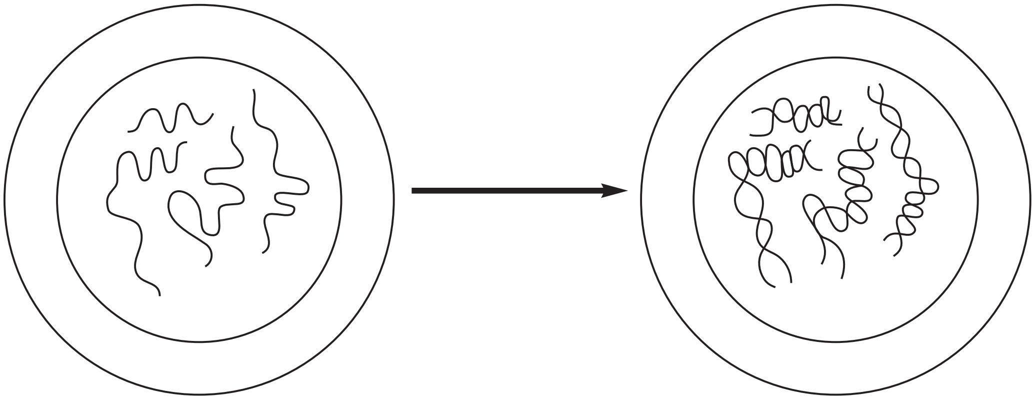
5. **Cytokinesis**

   At this point in cell division, there are two sets of nuclei in a single cell. The next step is called cytokinesis.

   The spindle fibres shorten, causing the double-stranded chromosomes to pull apart. One strand from each double will move to either end of the cell.

Animal cell cytokinesis takes place when the cytoplasm pinches off at the centre of the cell to form two cells. Each cell is complete with its own nucleus. Plant cell cytokinesis takes place as a new cell plate grows in the centre of the cell. Two new cells are formed as the cell plate completes its growth, each with its own nucleus.

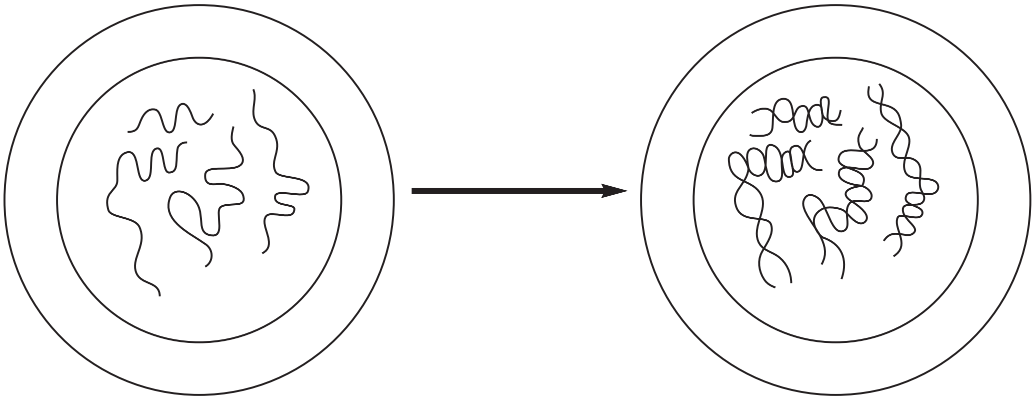
Figure 1.10 **Cytokinesis**



Interphase

"Inter" means between. Interphase represents that time between cell division when the cell grows and matures. The cell is in interphase for considerably longer than it is in cell division.

Figure 1.11 **Interphase**



Learning Activity 1.2: Stages of Mitosis

1. What happens to the nucleus of a cell before mitosis begins?
2. What is the purpose of mitosis?
3. Why is cytokinesis a necessary part of cell division?
4. What happens to the cell during interphase, the time in between cell division?

Check the answer key.

Summary

Cell division is the process of duplicating DNA, the genetic material of a cell, and dividing the copies among two separate cells. This process is known as mitosis, and is a part of the cell cycle, a continuous process of growth, DNA duplication, and division that all cells undergo.

LESSON 3: ASEXUAL REPRODUCTION

Lesson Focus

After completing this lesson, you will be able to

☐ describe several methods of asexual reproduction

☐ identify when each type of asexual reproduction is taking place

Key Words

- asexual reproduction
- binary fission
- budding
- sporulation
- fragmentation
- regeneration
- vegetative propagation

Introduction

Previously, you learned about the cell cycle and how single cells perform mitosis to reproduce themselves. Next, you will learn about how different organisms use mitosis. In simple organisms such as bacteria and fungi, mitosis is used to create offspring. More complex organisms such as animals and plants use mitosis to regenerate lost tissue and to heal.

Asexual Reproduction

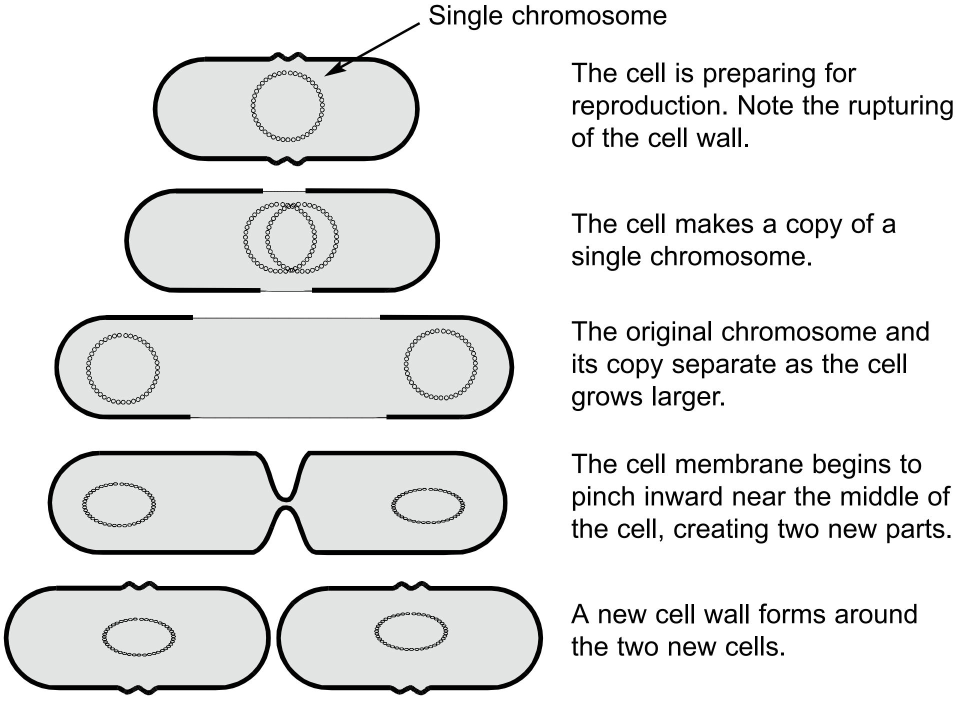
The cell cycle is essential for the growth and repair of cells in our body. Mitosis is the name we give the process of reproduction of single cells. Living organisms reproduce either sexually or asexually.

In **asexual reproduction**, a single organism generates an offspring with identical characteristics. The offspring is identical to the parent since there is only one parent from which it can gain its genetic information. Most single-celled organisms reproduce asexually. Some organisms are capable of reproducing asexually and sexually. The conditions determining which type of reproduction is to take place are often environmental.

Asexual Reproduction in Bacteria

Bacteria are one-celled organisms that do not have a true nucleus. Bacteria reproduce through a process of asexual reproduction called binary fission. In **binary fission**, the organism splits into two equal-sized offspring each containing a single chromosome carrying a complete set of DNA identical to the parent.

Figure 1.12 ***Binary Fission***



Asexual Reproduction in Fungi

Moulds, yeasts, and mushrooms are all fungi. Fungi possess filaments called hyphae that travel on the surface and into cracks of the material they grow on. The word "hyphae" comes from the Greek word *hyphos*, meaning web. Fungi reproduce two ways.

- **Budding**

  Yeast are well known for their ability to reproduce by budding. Yeast is an important part of bread production. When a yeast cell buds, it makes a copy of its nucleus. A tiny bud begins to form on the cell wall. The bud grows larger and eventually breaks off the cell wall to become a new yeast cell, taking along the new nucleus.

- **Spore Formation (Sporulation)**

  Moulds such as *Rhizopus* produce spores inside a case called a sporangium. Spores remain in the case until conditions are favourable for the reproduction of the spore cells. The spore cell reproduces by mitosis until the fungi is mature. One organism can produce very large numbers of spores.

Asexual Reproduction in Animals

Animals are either vertebrates (with backbones) or invertebrates (without backbones). Some of the invertebrate animals will reproduce asexually.

Sponges and hydra will reproduce by budding. Starfish will reproduce through fragmentation.

An interesting method of reproduction is found in some animals such as the *planaria* (or flatworm). A planaria will reproduce by **fragmentation**. If a planaria is cut into two parts, it will create two new whole planaria. If a single planaria is cut into three parts, three new whole planaria will result. If part of a planaria is cut but remains attached, it will regenerate the cut part. For example, if the head of the planaria is cut, two new heads will result. **Regeneration** is the ability of an animal to regrow a tissue, organ, or part of the body. Sponges are able to regenerate their whole body easily. If a sponge is squeezed through a screen and the living cells are allowed to touch, the sponge will reform itself.

It appears that animals with the least amount of cell specialization have the greatest ability to regenerate. Earthworms cannot reproduce their whole body by regeneration but they can regenerate certain parts of the body. Humans can regenerate only certain tissues such as blood, bone (to repair breaks), and outer skin (to repair cuts).

Vegetative Propagation

Plants are able to repair themselves and reproduce asexually like all other organisms through mitosis. When a shrub is trimmed, grass is mowed, or a tree is pruned, they are able to repair the damage and continue growing.

Vegetative propagation is the process by which a new organism is created from the roots, stems, or leaves of plants. For example, willow branches can develop roots and grow into a new tree and runners in strawberry plants can sprout roots and develop into a new plant. Several types of vegetative asexual reproduction include grafting, bulbs, tissue culture, runners, cutlings, cloning, and tubes.

Learning Activity 1.3: Asexual Reproductions

1. How does the daughter cell compare to the parent?
2. Describe one method of vegetative propagation.
3. Name two ways that fungi reproduce.
4. What name is given to the reproduction of bacteria?
5. Compare and contrast the way that humans and bacteria use mitosis.
6. List the type of asexual reproduction occurring in each scenario. Some types may appear more than once.
    a. a starfish regrowing a lost limb
    b. bread dough rising in a pan
    c. grass regrowing after it has been mowed
    d. staying home sick because of a bacterial infection
    e. roots developing out of a broken-off apple tree branch
    f. mold spreading over a loaf of bread
7. State three advantages and two disadvantages of asexual reproduction.

Check the answer key.

Summary

The cell theory states the following:

- All living things are made of one or more cells.
- A cell is the functional unit of life.
- All cells come from pre-existing cells.

This lesson has demonstrated that life can only proceed from life. All forms of living organisms from bacteria to humans make use of cell division by mitosis. In addition to cellular reproduction, you have seen that asexual reproduction provides for the reproduction of living organisms. The types of organisms that reproduce asexually include bacteria, fungi, animals, and plants.

Asexual reproduction always produces an offspring that is identical to the parent, since there is only one parent

Asexual reproduction has some advantages.

- It allows stationary organisms to easily reproduce.
- It allows reproduction with minimum expenditure of energy.
- It prevents genetic change that might be a disadvantage to the offspring.

Asexual reproduction also offers some disadvantages.

- Spore production is wasteful, as not all offspring typically survive.
- It can more easily lead to overcrowding and competition.
- There is no genetic variation to allow for adaptation and evolution.

Notes

LESSON 4: SEXUAL REPRODUCTION

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe the differences between mitosis and meiosis
- ☐ indicate which type of cells undergo mitosis and meiosis
- ☐ explain what haploid and diploid numbers represent
- ☐ describe how haploid gametes are produced in sexual reproduction (plants and animals)

Key Words

- sexual reproduction
- gametes
- fertilization
- zygote
- somatic cells
- reproductive cells
- sperm
- egg
- homologous pairs
- diploid
- haploid
- meiosis

Introduction

In the last lesson, you learned about how plants, fungi, and animals use mitosis. Simple organisms use mitosis for asexual reproduction, while complex organisms use mitosis for growth and the repair of body cells. You also learned that mitosis requires only one parent, and that offspring are identical to the parent.

However, you will have noticed that complex organisms such as animals and humans require two parents to produce offspring. In this lesson, we will discuss the process of **meiosis**, or sexual reproduction, and how it is used to create unique offspring by combining genetic material

Sexual Reproduction

Sexual reproduction usually requires two separate parents (excluding hermaphrodites) where specialized cells called **gametes** from each parent combine in a process called **fertilization** to form a new cell called a **zygote**. Note that two gametes combine to form one zygote. A gamete is a sexual reproductive cell with a single set of unpaired chromosomes. A zygote is the offspring of two parents.

Male Gamete + Female Gamete = Zygote (Offspring)

You know that your parents, brothers, sisters, and grandparents look different than you do, but a family portrait will likely demonstrate that there are strong similarities among the family. Sexual reproduction is responsible for these differences between the parents and their offspring.

Meiosis

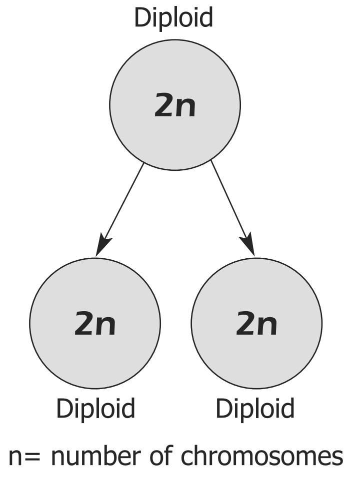
In complex plants and animals where sexual reproduction occurs, there are two types of cells.

- **Somatic cells** are the cells that make up our body. These cells include muscles, blood, the skeleton, and so on. These cells reproduce by mitosis.
- **Reproductive cells** are sex cells. These cells are specialized for producing offspring through sexual reproduction. There are two types of reproductive cells: the male reproductive cell is called **sperm** and the female reproductive cell is called the **egg**.

Human body cells contain 23 pairs of chromosomes for a total of 46 chromosomes per cell. The two chromosomes in each pair match each other in size and shape and are called **homologous pairs**. A cell with paired chromosomes is called **diploid**, ("di" means double).

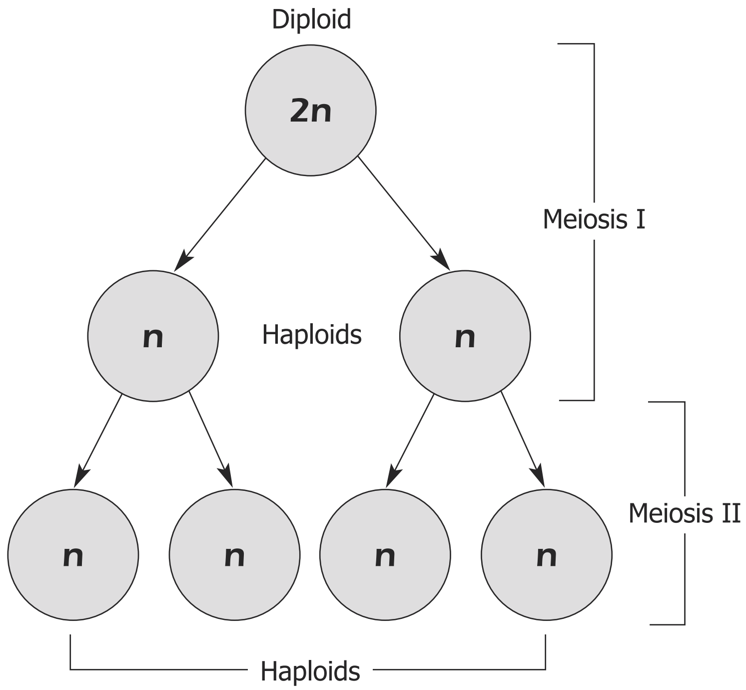
Diploid cells are represented by the term 2n, where n is the number of homologous pairs they contain. Dogs have 39 homologous pairs for a total of 78 chromosomes. Mice have 20 homologous pairs for a total of 40 chromosomes. When somatic cells reproduce through mitosis, each new cell receives the diploid number of chromosomes. Our human body cells created through mitosis will each receive 23 pairs of chromosomes (making 46 chromosomes overall).

Figure 1.13 **Mitosis**



In complex plants and animals, there are reproductive cells that have a haploid number of chromosomes. The chromosomes in these cells lack a matching partner, and are written as n. Sperm and eggs are both haploid. In humans, sperm and egg contain only 23 chromosomes as opposed to 46.

Figure 1.14 **Meiosis**



n= number of chromosomes

In order for sexual reproduction to occur, the sperm gamete must unite with the egg gamete. Once combined, the 23 chromosomes from the sperm and the 23 chromosomes from the egg will form a zygote with 46 chromosomes (or 23 homologous pairs). The sperm and the egg contribute one member of each homologous pair when they produce the diploid zygote. In other words, 23 halves link up with 23 halves for 23 wholes.

$n + n = 2n$

$23 + 23 = 2 \times 23$

$23 + 23 =$ chromosomes

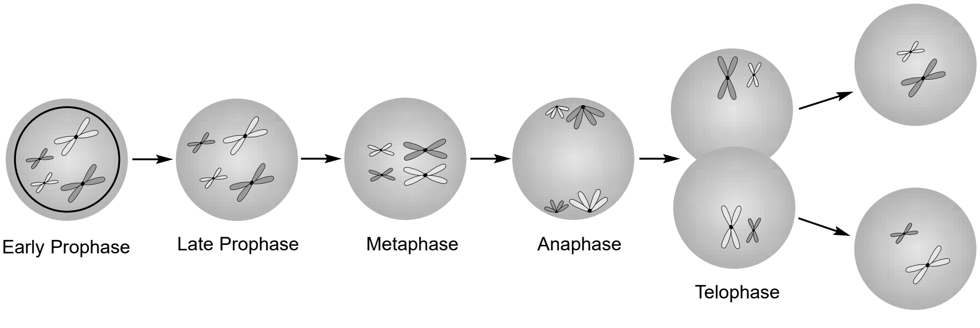
The haploid gametes are formed by a process called **meiosis**.

Although it is critical for you to understand the following stages of meiosis as a continuous and dynamic cycle, it is not necessary for you to memorize the names of each stage.

Stages of Meiosis

The first stage of meiosis is called Meiosis I. This stage is the reduction part of Meiosis. Each of the sex cells has its chromosomes reduced from a diploid number to a haploid number.

Figure 1.15 **Meiosis I**



The two daughter cells have 23 chromosomes at the end of meiosis I. The daughter cells each have a haploid number of chromosomes.

- **Early Prophase**

  The chromosomes do not appear to be double stranded, but they are because the homologous chromosomes have paired.

- **Late Prophase**

  The nuclear membrane begins to disappear. Homologous chromosomes begin to thicken and become visible. The spindle becomes visible.

- **Metaphase**

  The chromosome pairs line along the equator of the cell. Spindle fibres attach to each homologous pair.

- **Anaphase**

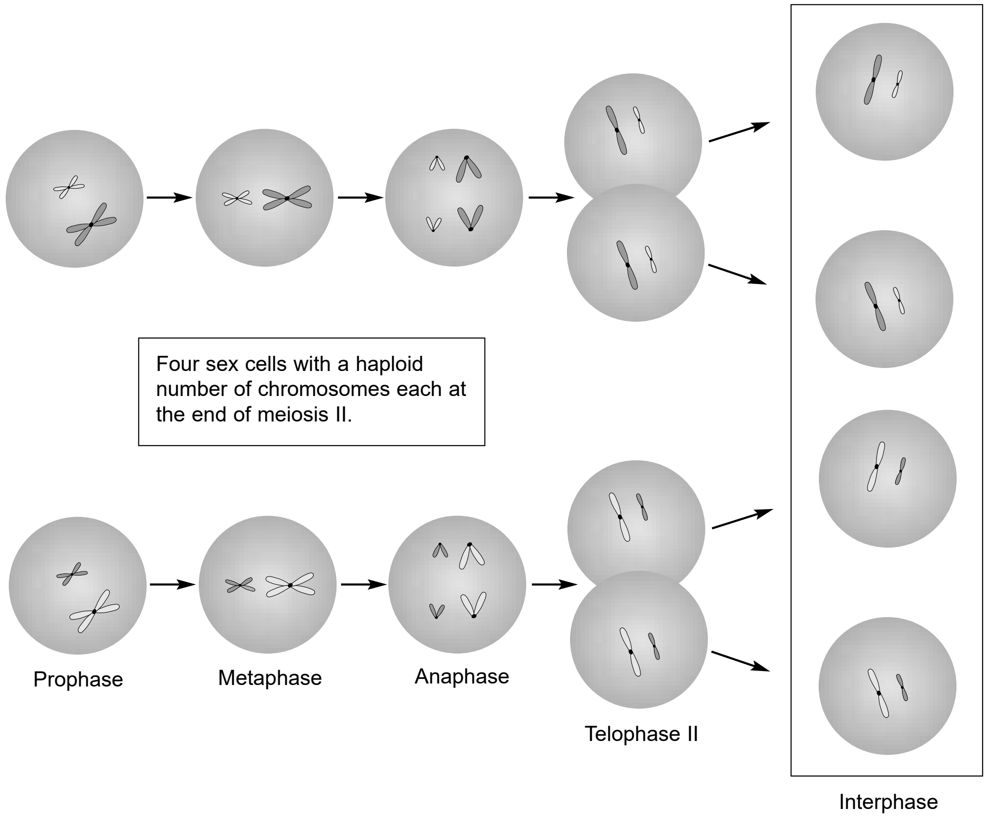
  The chromosome pairs are drawn to the opposite poles by the spindle fibres.

- **Telophase**

  The chromosome pairs move to the opposite poles and the cell divides to form two new cells, called daughter cells, each having a haploid number of double-stranded chromosomes.

The second stage of meiosis is called Meiosis II and is known as the division stage. Each daughter cell from Meiosis I divides to produce a total of four daughter cells.

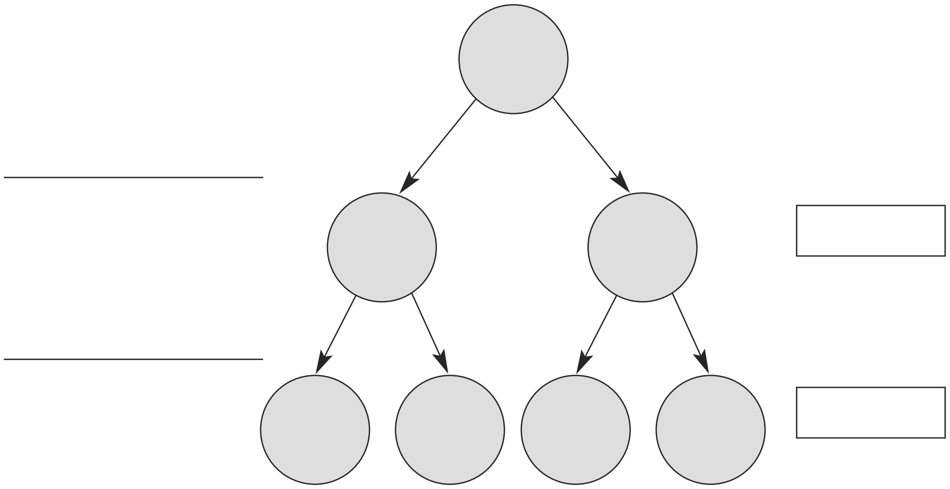
Figure 1.16 **Meiosis II**



The phases in the second stage are very much like the phases in mitosis. The difference lies in the number of chromosomes in the cells from Meiosis I. The two cells produced from Meiosis I have a haploid number of paired chromosomes. As Meiosis II takes place, the paired chromosomes are separated, leaving a haploid number of chromosomes in the four sex cells at the interphase. One parent cell produces four daughter cells, each of which have half the number of chromosomes found in the original parent cell.

Learning Activity 1.4: Meiosis

1. State two differences between a somatic cell and a reproductive cell.
2. State two ways in which asexual and sexual reproduction differ.
3.



   a. Place the number of chromosomes for human cells at each stage of meiosis in the box.
   b. Label the two stages of meiosis on the diagram.

4. What would happen to the offspring in sexual reproduction if meiosis did not occur?
5. An animal has 54 chromosomes.
   a. What is the diploid number for this animal?
   b. What is the haploid number for this animal?
   c. How many chromosomes does a gamete have?
   d. How many chromosomes does an egg have?
   e. When the egg and sperm combine, how many chromosomes are there?
   f. How many chromosomes does a cell taken from the animal's muscle have?

continued

Learning Activity 1.4 (continued)

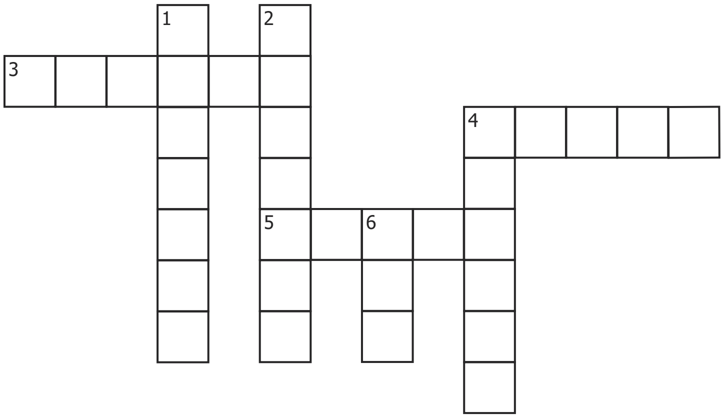
6. Fill in the blanks for the following statements.
    - a. A male gamete is called a(n) __________________ and a female gamete is called a(n) ____________________
    - b. When two gametes unite, they form a(n) __________________
    - c. The two stages of meiosis are ________________________ and ______________________.
    - d. During __________________reduction takes place.
    - e. One parent cell will produce ________________ daughter cells in meiosis.
7. What are the two characteristics that identify mitosis?
8. Complete the crossword puzzle shown below.

Across

3. the name given to a fertilized egg cell
4. parts of a chromosome
5. male gamete

Down

1. the name given to a body cell
2. sexual reproduction
4. the name given to a reproductive cell
6. female gamete



Check the answer key.

Summary

There are two types of cells. Somatic or body cells use mitosis to reproduce cells for growth and repair. These cells have a diploid number of chromosomes and are identical to the parent cell. Reproductive cells produce two types of gametes called sperm and egg. These cells have a haploid number of chromosomes so that when the sperm combines with an egg the offspring will have a diploid number of chromosomes.

There are two steps to complete cell reproduction by meiosis. The first step is a reduction step where the chromosomes are reduced from a diploid number to a haploid number. This step is called Meiosis I. The next step is a division step where the two daughter cells divide to produce four daughter cells. This step is called Meiosis II.

Notes

LESSON 5: SEXUAL REPRODUCTION IN PLANTS AND ANIMALS

Lesson Focus

After completing this lesson, you will be able to

☐ draw diagrams illustrating the formation of egg and sperm sex cells

Key Words

- gonads
- testes
- ovary
- pistil
- stigma
- stamen
- anthers
- pollen
- pollen tube
- embryo

Introduction

Now that we have discussed the general process of meiosis, we can examine in further detail how animals and plants perform sexual reproduction, as well as the unique structures each group uses to produce reproductive cells.

Sexual Reproduction In Animals

You know from experience that there are a great number of different types of animals. Some animals live in water, some are truly unique to their location, but all have a common reproductive sequence.

- Gametes are formed by meiosis.
- The male gamete (sperm) combines with the female gamete (egg).
- The embryo develops through cell division (mitosis) to a mature offspring.

Sperm and Eggs

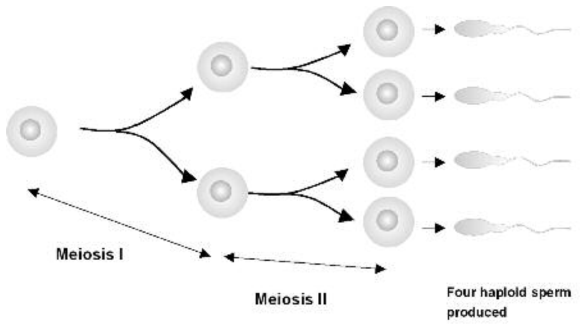
Most animals have two sexes. The male produces sperm and the female produces eggs. The gametes are produced in reproductive organs called **gonads**.

- **Sperm**

  Sperm are produced in the male gonad called testes.

  Since the sperm contain four different sets of genetic information, they are capable of producing four different offspring, depending on which sperm fertilizes the egg.

Figure 1.17 SPERM PRODUCTION



- **Eggs**

  Female gonads are called ovaries.

  Only one egg cell receives enough cytoplasm to survive.

Figure 1.18 EGG PRODUCTION

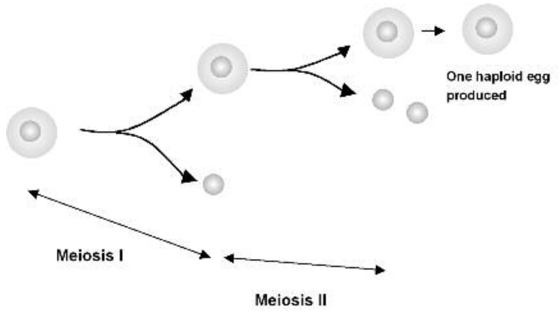
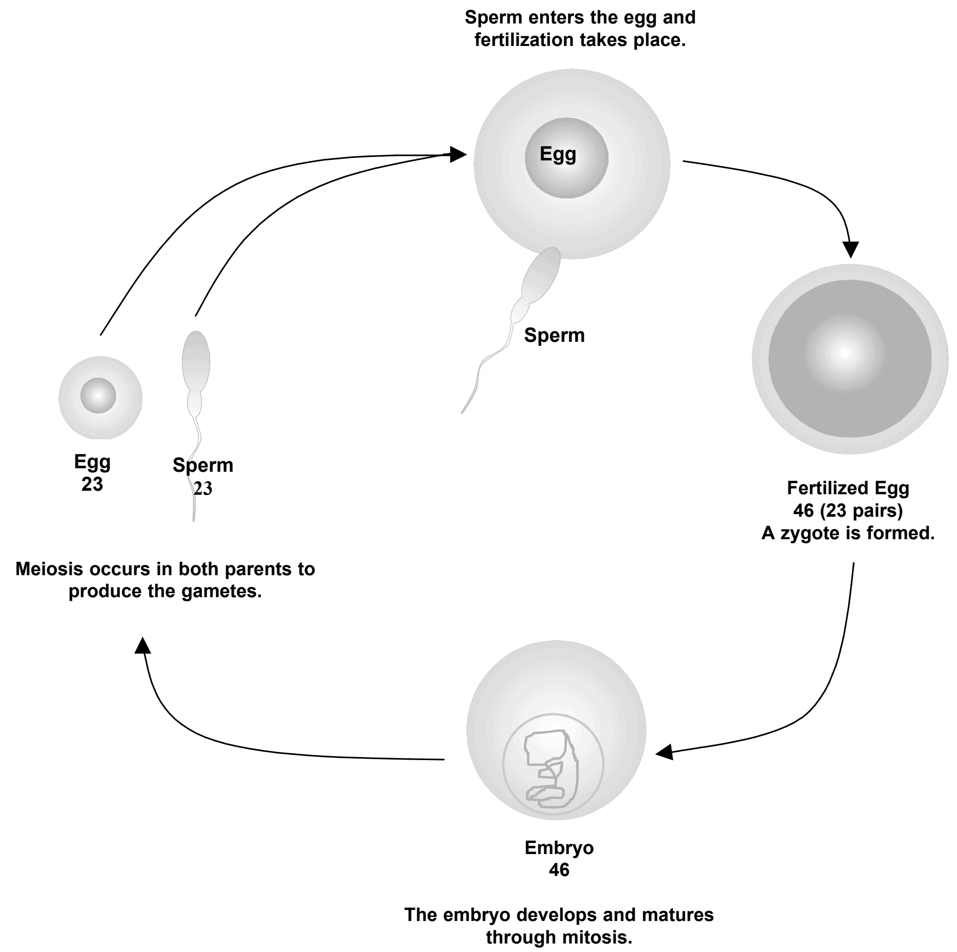


Figure 1.19 below shows the process of fertilization where two gametes with 23 chromosomes each combine to form a single zygote with 23 pairs of chromosomes (46 chromosomes). Notice that cell duplication occurs by mitosis after fertilization has taken place.

Figure 1.19 **FERTILIZATION PROCESS**



The cycle shown above illustrates how meiosis is necessary for gametes to be produced. Once fertilization has occurred, mitosis reproduces the single cell until an embryo is produced and eventually birth occurs.

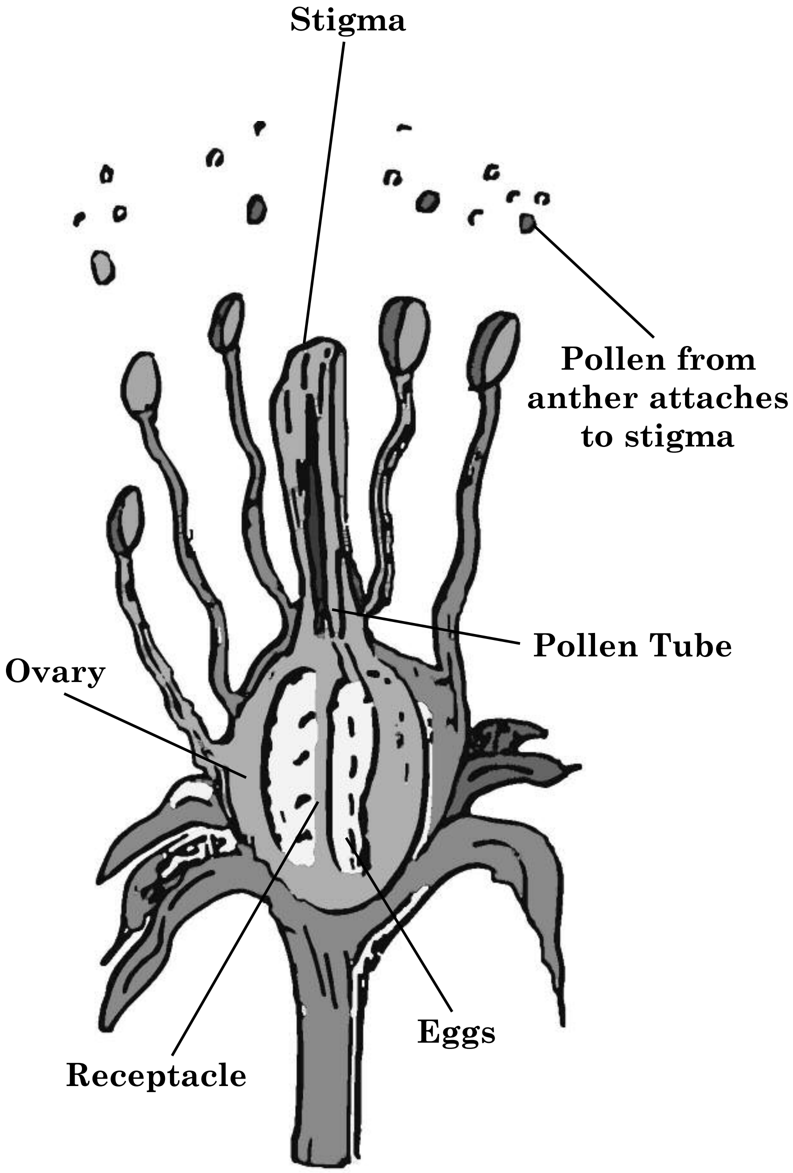
All animals must meet two requirements for the cycle to be completed.

- The male and female gametes must come together.

  Mating is the process whereby the male and female come together for combining gametes. Some animals mate once per year timed so the offspring will be born when weather conditions are favourable.
- The zygote must receive food, moisture, warmth, and protection.

Sexual Reproduction in Plants

Figure 1.20 **Reproduction in Plants**



In plants, **pistil** is the name given to the female reproductive structure. Often shaped like a flask, it consists of the **stigma** (lip), and **ovary**.

Stamen is the name given to the male reproductive structure. It consists of the **anthers** which are the source of **pollen**, the male sex cell in plants. Plants may self-pollinate (both gametes come from the same plant) or cross-pollinate (each gamete comes from a different plant). In both cases, the pollen must attach to the stigma.

Pollen grows a pollen tube to the egg through the pistil. The nucleus of the pollen grain travels down the pollen tube to the egg in the ovary where fertilization occurs. After fertilization, the egg develops into an embryo. After some time, seeds are produced.

The process of fertilizing egg cells is the same in plants as in animals. There is a male sex cell (pollen) and a female sex cell (egg) which must combine to form the zygote. The zygote in turn develops into an embryo and eventually the seed is produced.

Learning Activity 1.5: Animal and Plant Reproduction

1. Name the male and female sex cells in animals.
2. Where are the male and female sex cells produced in animals?
3. Name the male and female sex cells in a plant.
4. Describe the process of sexual reproduction in a plant from pollen touching the stigma to fertilization.
5. What type of cell reproduction takes place after the egg cell is fertilized?
6. An animal has 64 chromosomes.
    a. What is the haploid number for this animal? ________
    b. What is the diploid number for this animal? ________
    c. How many chromosomes will its sperm have? ________
    d. How many chromosomes will be found in its liver cells? ________
7. Describe the cells produced during Meiosis I. How are they different from the cells produced by Meiosis II?

Check the answer key.

Summary

Both plants and animals have sex cells, or gametes. In animals, the male gamete is called sperm, and in plants, the male gamete is called pollen. Both groups refer to the female gamete as the egg. In both cases, the male and female gametes must combine to produce a zygote, which develops through mitosis into an embryo.

LESSON 6: REPRODUCTIVE SUCCESS

Lesson Focus

After completing this lesson, you will be able to

- ☐ compare the advantages and disadvantages of asexual and sexual reproduction
- ☐ describe situations where one type of reproduction is more advantageous than the other
- ☐ determine whether an example illustrates sexual or asexual reproduction
- ☐ describe adaptations of plants and animal species that enhance reproductive success

Key Words

- genetic variation
- adaptation
- conjugation

Online Resources

The following website explores the value of biodiversity.

- The Medical Journal of Australia
  http://www.mja.com.au/public/issues/xmas98/cassis/cassis.html

Introduction

By now you should be familiar with the processes of mitosis and meiosis, and the ability of an organism to reproduce either asexually (mitosis) or sexually (meiosis), but did you know that some organisms such as bacteria, flatworms, and sea stars are able to use both methods?

What advantages are there to each form of reproduction? Why would it be helpful to produce genetically identical copies, as opposed to individualized offspring? Keep these questions in mind as we discuss the pros and cons of each option.

Reproduction

As you have learned, plants and animals must reproduce for several reasons. One of the reasons for reproduction is survival of the organism. Reproduction can take place two ways, either sexually or asexually.

The table shown below gives you a brief summary of the two methods of reproduction.

Asexual Reproduction	***Sexual Reproduction***
One parent	Two parents
All genetic information is passed to offspring from one parent.	Each parent contributes one-half the genetic information to offspring.
Offspring is genetically identical to parent.	Offspring has combination of genes from both parents.
Genetic differences are rare and come from mutations.	Allows greater genetic variation since offspring will always differ from parents and other offspring.

Reproduction exists in two forms but there are variations within these forms.

How do the two types of reproduction contribute to the success of the organism?

Reproductive Success and Asexual Reproduction

Generally, primitive organisms use asexual reproduction. Primitive organisms include bacteria, hydra, yeast, and planaria as examples. Of course, every generalization has exceptions. The exceptions in this case are plants that reproduce by vegetative reproduction even though they are complex organisms.

There are some advantages to asexual reproduction.

- Every organism is capable of reproduction. Organisms that reproduce asexually are capable of increasing their populations at very high rates. We have all experienced the effects of high reproduction rates in bacteria. Bacteria are capable of reproducing both sexually and asexually. When conditions are favourable, they choose asexual reproduction for its high rate of producing new offspring. Our throats offer a favourable medium for bacteria. We experience this negative effect by developing a sore throat
- Identical offspring take full advantage of a favourable, static environment; no time or energy is wasted by genetic variation.
- Plants and animals that cannot move are capable of reproduction. Many primitive organisms are either incapable of moving or have limited mobility. Asexual reproduction is an efficient method for them to produce offspring.

Reproductive Success and Sexual Reproduction

The most significant difference between asexual and sexual reproduction is the **genetic variation** that results from meiosis.

Gametes finish up with a mixture of characteristics from both parents. There are both costs and benefits to this method of reproduction. The benefits must outweigh the costs since sexual reproduction is the most common method of producing offspring.

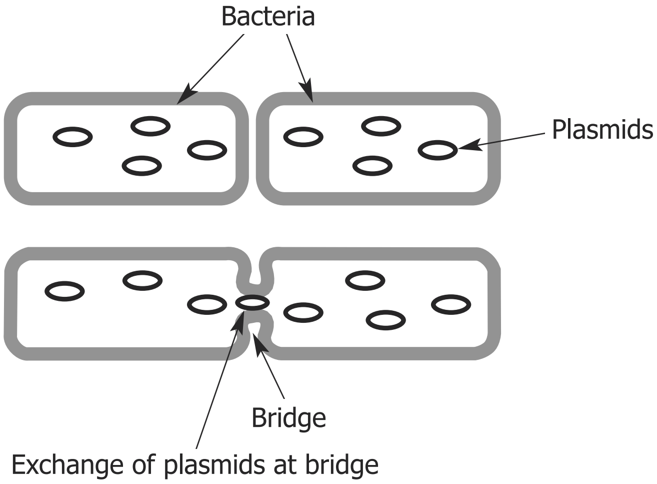
Some of the costs include the following:

- Sexual reproduction does not make particularly efficient use of its resources. Only females reproduce. Males take up 50 percent of any population.
- Mating consumes time and energy. Mating often makes the individuals vulnerable to attack from other animals.
- Genetic variability can be unnecessary in a static environment.

The benefit of genetic variation outweighs the costs.

- Genetic variation is an advantage in an environment that is under stress. Most environments are under constant change. A species must be under constant change to survive. The environmental and species change referred to in this case usually takes place over many years. We would not expect change to take place over a few weeks.
- Hermaphrodites have both reproductive organs in the same plant or animal. While the organism reproduces sexually, there is only one parent. Stationary plants and animals may reproduce this way since their immobility makes it difficult to find a mate.
- Bacteria reproduce asexually under beneficial environmental conditions. Bacteria are also capable of reproducing sexually if the environment becomes hostile. Bacteria reproduce sexually by a process called **conjugation**. In conjugation, two bacteria contact each other, form a bridge, and exchange pieces of genetic information contained in plasmids. Plasmids are small loops of DNA that can be transferred from one bacterium to another as shown in Figure 1.21.

Figure 1.21 **Conjugation**



Advantages and Disadvantages of Sexual and Asexual Reproduction

	Advantages	Disadvantages
Asexual Reproduction	■ Asexual reproduction produces a new organism that is genetically identical to its parent. ■ There is no need to find a partner. ■ It takes energy to produce offspring sexually. ■ Offspring is usually well adapted to its environment because of the success of the parent. ■ An area favourable to the parent can quickly be colonized due to the high number of offspring the parent can generate in little time. ■ Offspring are often already multicellular and more viable.	■ Asexual reproduction does not give rise to genetic variability in organisms of a same species. ■ The species does not adapt at all or adapts very slowly when circumstances change. ■ There is only one parent to take care of offspring. ■ The parent sometimes disappears because its body no longer exists (fission). ■ An asexual species runs the risk of suddenly disappearing because of a catastrophe that affects all organisms of the species that are genetically identical.

	Advantages	Disadvantages
Sexual Reproduction	■ Sexual reproduction produces a new organism that results from a combination of traits of two parents. ■ Sexual reproduction increases the genetic viability in organisms of the same species and even within the offspring of one couple. ■ In the long run, sexual reproduction allows the best adaptations to be widespread within a species, especially in changing circumstances. ■ The variability of the offspring within a species guarantees that a higher proportion will survive in perilous circumstances. ■ Two parents can watch over offspring.	■ Finding a reproductive partner and producing gametes requires the output of a lot of energy. ■ Mechanisms for the transport of gametes for fertilization, for the attraction of the opposite sex, and for competition within a species must be put in place. ■ Not only are two gametes needed for fertilization, one must be male and the other female. ■ The genetic results of meiosis, and often fertilization, are unpredictable. ■ Genetic "errors" happen more frequently because meiosis is more complex than mitosis and diploid organisms have more chromosomes to double. ■ Offspring are not necessarily as well adapted to their environment as the parents. ■ Many organisms never become parents because they can't find a partner; many gametes are lost because they are not fertilized.

Reproductive Success through Adaptation

Many plants and animals have survived by changing one or more of their characteristics. Plants and animals may have survived through a change in colour, a change in behaviour, or many other possibilities. Changes that continue to exist are those that are successful in keeping the species alive.

The environment can become hostile, predators can become more numerous or more adept at catching their prey, and food can be more difficult to find. Mating is a part of reproduction in complex organisms. Mating can be the most dangerous time for plants and animals, so they often develop mating habits that have built-in security features. We will explore some of these adaptations in more detail.

A brief list of some forms of adaptations that enhance reproductive success is shown below.

- **Behaviour**

  Animals that fertilize internally demonstrate more care for their young than animals that fertilize externally. The embryo remains in the female parent until it reaches a level of maturity that ensures greater success for survival. Once the offspring is born, the parents make an effort to protect it until it can feed and protect itself. The time it takes for that level of maturity can range from a few days to a few years.

- **Appearance**

  Plants, like many animals, have internal fertilization of eggs. However, unlike animals, plants cannot move about to seek a suitable mate. They must somehow bring female and male together without moving, so they use wind, water, and mobile animals to aid in their reproduction.

  As flowering plants were developing, insects and animals that could pollinate these flowering plants were also developing. In fact, flowering plants and the insects and animals that pollinate them—their pollinators—seem to have developed in such a way that they both help each other to survive.

  Birds are flowering plant pollinators. All birds see colours, but especially prefer red and other bright colours. A bird looking for nectar would choose brightly coloured flowers rather than white flowers, and would choose flowers which are large enough for it to fit its beak into. As the bird feeds on the pollen, pollen sticks to its body and is carried to other flowers. Birds with long beaks would have more success in feeding on nectar than short-beaked birds. So long-beaked birds would survive and reproduce, and the number of long-beaked birds would increase. In a similar process, because the brightly coloured flowers attract these long-beaked birds, they would also survive and reproduce because the long-beaked birds would choose them and therefore pollinate them. Over time, both the population of long-beaked birds and brightly coloured flowers would increase because they help each other to survive. Because these flowers and their pollinators help each other to survive, their numbers would increase over time and they would grow and flourish everywhere. In this example, both the bright colours of the flowers and the long beaks of the birds are adaptations which affected the natural selection of these organisms as survivors.

If you look closely, you can tell what characteristics of other flowers and their pollinators have been helpful to their survival.

Butterflies have long, slender tongues, and will pollinate long, narrow flowers. However, butterflies still need a place to land while they are feeding on the flower's nectar, so these same flowers usually grow straight up and have clustered petals that give the butterfly a landing platform. In addition, butterflies seem to choose white, cream, yellow, pink, and blue flowers in pastel colours.

Many insects also prefer flowers that have nectar guides on the flower petals. These guides lead the insect to the source of the nectar, and different flowers have very distinctive nectar guides. Many of these guides can only be seen under an ultraviolet light, a wavelength of light that can be seen by insect.

Hummingbirds are the most common bird pollinators. They choose large, tube-shaped flowers to match their long beaks. They choose flowers with lots of nectar because the hummingbirds need lots of food energy to survive. The flower's anthers stick out above the petals so they are more likely to brush against the hummingbird and pick up pollen. Hummingbirds see red and yellow well, but have an underdeveloped sense of smell, so they often choose bright flowers with little fragrance.

- **Mating Calls**

  Mating calls are universal. Mating calls have several characteristics in common for all types of animals.

  - Mating calls attract females.
  - Mating calls can indicate the desirability of the calling male.
  - Mating calls can establish territories, allowing only the most fit males to mate.
  - Mating calls can identify species in order to reduce energy lost in attempting mating with another species for which there will be no offspring.

The mating calls of whales are song-like and can be melodic and elaborate. Prairie chickens use their wings to make a booming sound. Elephants make extremely low frequency sounds that only other elephants can hear. Elk make the famous bugling sound that is such a part of the Canadian wilderness.

- **Chemical Cues**

  Animals are capable of producing chemical hormones called pheromones that are responsible for sending messages to another animal of the same species. There are receptors called vomeronasal organs (VNO) located in the nose which are capable of detecting the presence of the hormone. Research indicates that the detection of pheromones is unconscious, but a pathway from the nose to the brain means the presence of pheromones has an impact on animal behaviour.

  Pheromones were first isolated in experiments with silk moths. Pure pheromones were placed near a silk moth causing it to begin a vigorous flutter dance which was a mating ritual for the species.

  It seems that pheromones are responsible for stimulating a mating response from males when they receive even a small amount of the hormone. Pheromones are also responsible for creating social and aggression cues in groups of the same species.

  Pheromones are now used as a natural insecticide. A pheromone spray placed over a crop will cause its natural predators to become confused. The confusion results in low reproduction rates and, accordingly, the species population diminishes in size.

  Some companies have begun advertising their pheromone-based scents that guarantee the attractiveness of the user to the opposite sex. Research, however, has shown that humans are considerably more complex than silk worms, and the advertising claims have not lived up to their promise, much to the disappointment of users.

- **Courtship Behaviour**

  The courtship behaviour of the ruffed grouse is similar to the basic elements of courtship behaviour in many animals.

  The ruffed grouse cups its wing and moves it rapidly through the air, causing a booming sound. The grouse performs this ritual while standing on an old log. The courtship ritual is thought to have two functions.

  — The male grouse attracts female grouse that are ready to mate.

  — The male grouse is letting other males know that this is his territory and they had better leave.

- **Number of Offspring Produced**

  Plants and animals that do not exert any effort in protecting the young, either before or after birth, will produce many offspring. The large number of offspring ensures that some will survive. More advanced plants and particularly animals that spend time with their offspring teaching them survival techniques will produce less offspring, as their potential for survival is greatly increased.

Learning Activity 1.6: Reproductive Success

1. Name two advantages of asexual and sexual reproduction.
2. Name five ways that sexual reproduction is enhanced by adaptation.
3. Appearance is an important element of reproductive success. For the following scenarios, decide which organism would stand a better chance of reproducing, and explain your choice.
   a. an Arctic hare with a pure white coat or an Arctic hare with a spotty, brown coat
   b. a large caribou with a large rack of antlers or a gangly caribou with one antler broken off
   c. a flower with bright red petals or a flower with spotted, black petals

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Check the answer key.

Summary

Asexual reproduction is favoured by a static environment to which the parent organism is already well adapted. Creating many identical offspring requires considerably less energy and can allow a species such as bacteria to quickly colonize an area. On the other hand, species that reproduce asexually run the risk of being wiped out by sudden environmental changes.

Sexual reproduction combines the genetic traits of both parents, and creates a variety of offspring that can better adapt to changing environments. Sexual reproduction allows a species to adapt, and pass on successful traits such as behavior, appearance and chemical cues. On the downside, sexual reproduction requires two members of a species, a great investment of time and energy, and offspring are vulnerable to genetic “errors” or mutations.

Assignment 1.1: Dual Option Assignment

For this assignment, you must complete one of two options. Option A is based on content from Lessons 1 to 3, while Option B is based on content from Lessons 4 to 6.

You may wish to work on this assignment with a learning partner. If your learning partner is also registered in this course, please submit your own work that is representative of your knowledge and understanding.

Option A: Asexual Reproduction in Agriculture ***(30 marks)***

Farmers and gardeners typically make use of asexual reproduction when growing crops and plants. Choose two of the following asexual reproduction techniques and write a report describing how these techniques work, what plants use the technique, and how the technique benefits agriculture or gardening.

- grafting
- bulbs
- tissue culture
- runners
- cuttings
- cloning
- tubers

You can present your research as a written report, a poster, or a PowerPoint presentation.

Make use of the Internet, your local library, or any community members with a "green thumb" to help you with your research. Your report will be assessed using the following rubric:

Content	Length and Style	Sources Used	Grammar, Neatness, and Spelling	Total Marks
20 marks (10 marks x 2 techniques)	3 marks	3 marks	4 marks	30 marks
What is it? Describe how the technique works. *(4 marks)* **What uses it?** Describe what kinds of plants or agricultural crops use this technique. *(2 marks)* **What about us?** Explain how this technique can benefit agriculture or gardening. *(4 marks)*	**Report:** At least 1 typewritten page, double-spaced, using a font no larger than 12. **PowerPoint:** At least 6 slides. Text is in a font and colour that is easy to read. Uses backgrounds, transitions and pictures to enhance the presentation. **Poster:** Clear title and sub-headings. Text is organized into sections. Uses colour and pictures to capture attention.	Include a "Works Cited" page/slide/section at the end of your presentation that details all of your research resources. **Books:** Include the title, author, and publisher. **Internet Resources:** Include the page title, author, and URL. **Interviews:** Include the name, occupation, and place of work of each person you interview.	Half-mark removed for each error.	
/20	**/3**	**/3**	**/4**	**/30**

Option B: Reproductive Success in Wildlife *(30 marks)*

Choose an animal, and research the adaptations developed by that species in order to maximize its reproductive success. Be sure to consider all the categories mentioned in Lesson 6, including behaviour, appearance, mating calls, chemical cues, courtship rituals, and number of offspring.

You can present your research as a written report, a poster, or a PowerPoint presentation.

Make use of the Internet, your local library, or any wildlife experts from your community to help you with your research. Your research will be assessed using the following rubric:

Content	Length and Style	Sources Used	Grammar, Neatness, and Spelling	Total Marks
20 marks	3 marks	3 marks	4 marks	30 marks
■ clearly states chosen species *(2 marks)* ■ discusses how reproductive success is (or is not) influenced by – behaviour – appearance – mating calls – chemical cues – courtship rituals – number of offspring *(8 marks)* ■ explains in detail how the six above factors are used by the species *(10 marks)*	**Report:** At least 1 typewritten page, double-spaced, using a font no larger than 12. **PowerPoint:** At least 6 slides. Text is in a font and colour that is easy to read. Uses backgrounds, transitions and pictures to enhance the presentation. **Poster:** Clear title and sub-headings. Text is organized into sections. Uses colour and pictures to capture attention.	Include a "Works Cited" page/slide/section at the end of your presentation that details all of your research resources. **Books:** Include the title, author, and publisher. **Internet Resources:** Include the page title, author, and URL. **Interviews:** Include the name, occupation, and place of work of each person you interview.	Half-mark removed for each error.	
/20	**/3**	**/3**	**/4**	**/30**

Notes

LESSON 7: HUMAN REPRODUCTION—THE MALE REPRODUCTIVE SYSTEM

Lesson Focus

After completing this lesson, you will be able to

- ☐ name the parts of the male reproductive system
- ☐ describe how the various parts work to produce and store sperm
- ☐ describe the structure and function of sperm and semen
- ☐ explain the function of hormones in the male reproductive system

Key Words

- sperm
- egg
- scrotum
- epididymis
- vas deferens
- prostate gland
- seminal vesicle
- urethra
- testes
- seminiferous tubules
- puberty
- androgens
- hypothalamus
- pituitary gland
- lutenizing gland
- follicle stimulating hormone
- testosterone

Online Resources

The following website provides an explanation of the human reproduction system.

- Michael J. Farabee
  http://www2.estrellamountain.edu/faculty/farabee/biobk/biobooktoc.html

Introduction

You have been studying sexual reproduction in the last few lessons. Questions regarding human reproduction are relevant. What do sex cells in humans look like, how are they produced, and where do they come from?

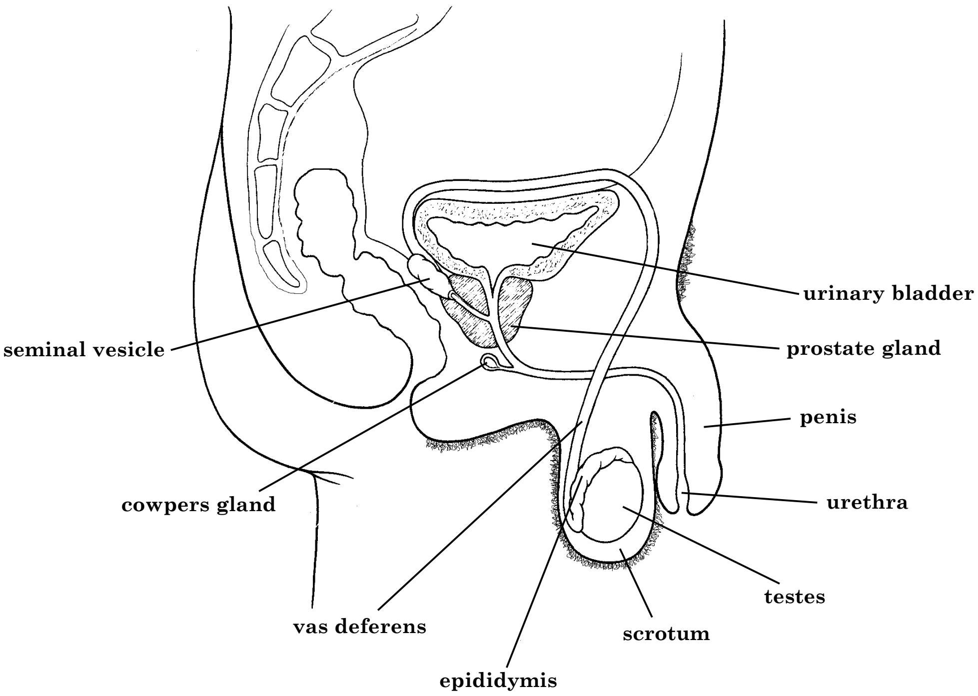
You will spend the rest of your time in Module 1 studying human reproduction. First you will study how reproduction takes place, then you will study how characteristics are transferred from one generation to the next, and finally you will study how modern technology can affect reproduction and the transfer of inherited characteristics.

The Structure of the Male Reproductive System

The male reproductive system functions as a producer of sperm. You will recall that sexual reproduction requires gametes from both parents. The male gamete is called **sperm**. In order for fertilization to occur, sperm must unite with the female gamete called the **egg**.

The male reproductive system must both produce sperm and pass the sperm on to the female. You are going to describe the function of the various parts of the male reproductive system. As you complete the task, keep in mind the two main functions of the male reproductive system.

Figure 1.22 **Male Reproductive System**



The diagram shown above illustrates the male reproductive system in humans. Each labelled part has an important function in the process of reproduction.

Scrotum: a pouch of skin that regulates the temperature of the testes by raising or lowering them

Epididymis: a long, crooked duct on the testis where sperm are stored

Vas deferens: the duct that carries sperm from the epididymis to the ejaculatory duct and urethra; the tube connecting the testes to the urethra

Prostate gland: a gland that is located near and that empties into the urethra, which produces a secretion that improves sperm viability

Seminal vesicle: glands that contribute fructose to sperm—the fructose serves as an energy source

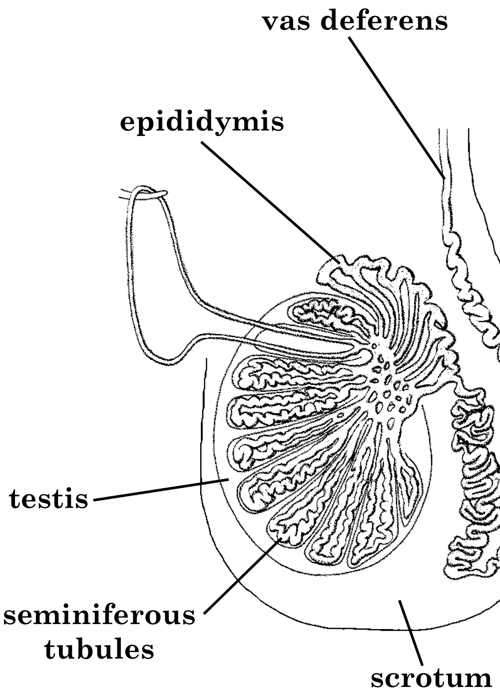
Urethra: a narrow tube that transports urine from the bladder to the outside of the body—in males, it also conducts sperm and semen to the outside

Testes (*singular* testis): the male gonads that produce sperm and male sex hormones—they are paired organs that contain seminiferous tubules in which sperm are produced

Developing the Male Sex Cell

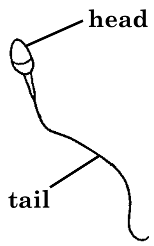
Sperm is produced in the seminiferous tubules. **Seminiferous tubules** are folded on each other to form a long tube approximately 70 centimetres in length. These tubules are responsible for producing huge amounts of sperm, up to 500 million in a day. Each sperm is a single cell containing 23 chromosomes (haploid number). Only one sperm is needed to unite with an egg cell in the female to cause fertilization. Why are so many sperm produced? One reason arises from the need for the sperm to travel from the male to the female sex organs. The journey is hazardous for the sperm, so the large numbers help make certain some will survive and fertilize the egg in the female.

Figure 1.23 **Sperm Production**



A sperm has two parts, a head and a tail, as shown in the diagram below. The head contains the genetic material that is to be transferred to the egg. The head also contains an entry capsule made of chemicals that are capable of allowing the sperm to enter the egg. The tail (flagella) provides the mobility the sperm needs to travel to the egg. The tail moves back and forth, propelling the cell to its destination.

Figure 1.24 **Sperm**



Once the sperm leave the seminiferous tubules, they are stored in the **epididymis** until they leave the body. The seminiferous tubules and the epididymis are located in the **scrotum**. The scrotum is maintained at a constant temperature to provide the sperm with optimum conditions for production and storage.

To help the sperm move from the male to the female, three glands produce a fluid. The three glands are called the **prostate gland**, the **cowpers gland**, and the **seminal vesicles**. The fluid, called **semen**, is placed in the vas deferens.

The **vas deferens** leads to the urethra where semen can travel through the penis into the female. The urethra has a dual function: it can either eliminate urine or semen. A small muscle at the bottom of the bladder allows only semen or urine to pass through the urethra at one time.

Male Hormones in Reproduction

Male sex hormones are essential for proper functioning of the reproductive system. The male and female embryos are identical until the seventh week following fertilization. At the seventh week a hormone is released in the embryo instructing it to produce male (or female) sexual structures.

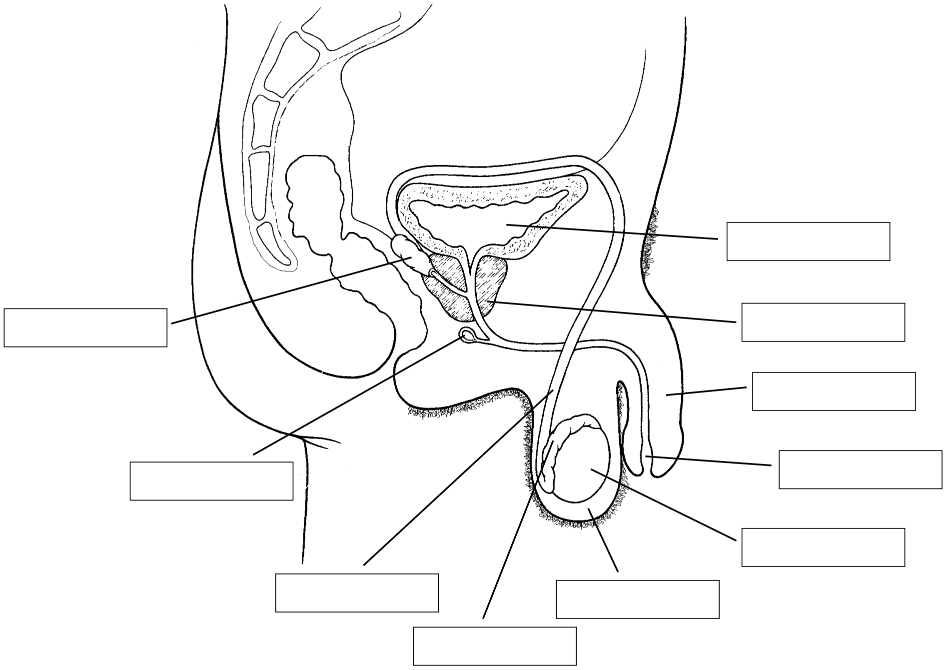
Once the offspring is born, there are only small amounts of sex hormones released. These sex hormones help regulate the male sex organs but they do not activate until the offspring reach **puberty**. At puberty, the brain instructs the body to begin rapid growth and to reach sexual maturity. At this time, the brain also begins the production of male sex hormones called **androgens**.

The part of the brain responsible for androgens is called the **hypothalamus**. The hypothalamus releases a hormone to the **pituitary gland**. The pituitary gland, in turn, releases two **hormones: lutenizing hormone (LH) and follicle stimulating hormone (FSH)**.

- LH travels to the testes and stimulates cells to produce testosterone. Testosterone is the most abundant male sex hormone and is responsible for the male characteristics listed below. These characteristics begin to show at puberty.
    - Onset of sperm production
    - Sexual organs grow and develop.
    - Voice changes, muscle and bone grow.
- FSH combines with testosterone to stimulate the production of sperm.

Learning Activity 1.7: The Male Reproductive System

1. What are the main functions of the male reproductive system?
2. Label the parts shown on the diagram below.



3. What part of the brain is responsible for the production of hormones?
4. What two hormones are produced in the pituitary gland?
5. Where is the hormone testosterone produced?
6. What functions does testosterone have?

continued

Learning Activity 1.7 (continued)

7. Write a brief description of the function of the sex organ or hormone in the table below.

Sex Organ/ hormones	Function
urethra	
epididymis	
testes	
vas deferens	
prostate gland	
seminal vesicle	
scrotum	
androgens	
LH	
FSH	

Check the answer key.

Summary

The male reproductive system provides for the production and storage of sperm. The structure of the male reproductive system is established at the seventh week of embryo development. The male reproductive system is non-functioning until puberty. At this time, the hypothalamus signals the pituitary gland to release LH and FSH to the testes where, with testosterone, the production of sperm takes place.

Notes

LESSON 8: HUMAN REPRODUCTION—THE FEMALE REPRODUCTIVE SYSTEM

Lesson Focus

After completing this lesson, you will be able to

☐ name the parts of the female reproductive system

☐ describe how the various parts work to produce and store egg cells

☐ describe the structure and function of egg cells in reproduction

☐ explain the function of hormones in the female reproductive system

Key Words

- vagina
- cervix
- uterus
- ovary
- oviduct
- follicle
- ovulation
- corpus luteum
- fertilization
- endometrium
- menstrual cycle
- menstruation
- estrogen
- progesterone
- follicular phase
- ovulation
- luteal phase
- menstrual cycle

Online Resources

The following website provides an explanation of the human reproduction system

- Michael J. Farabee
  http://www2.estrellamountain.edu/faculty/farabee/biobk/biobooktoc.html

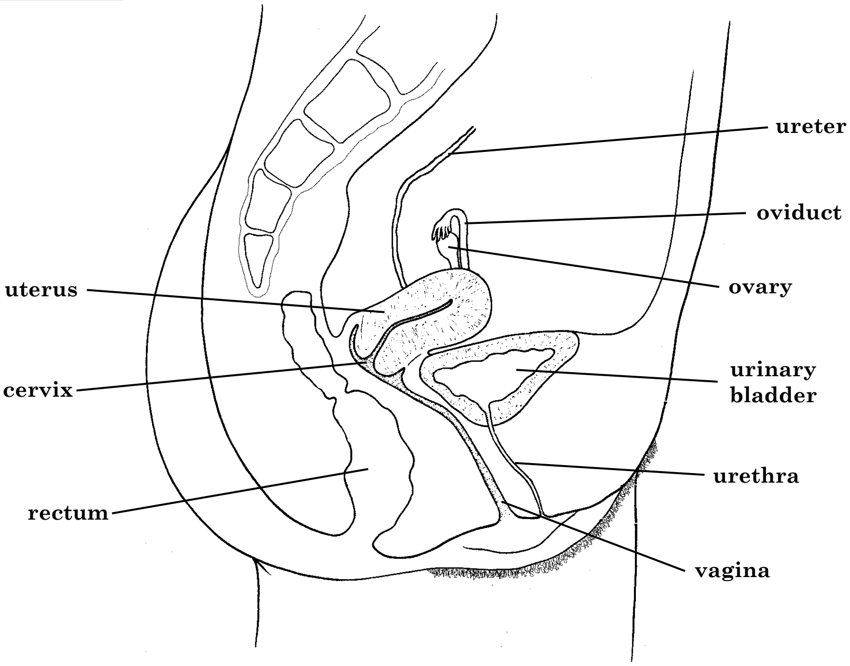
Introduction

This lesson will complete our discussion of human reproductive systems by listing the structures of the female reproductive system's structures, and explaining their roles in fertilization, development of the embryo, and birth. This lesson will also cover the role of hormones in the female reproductive system.

The Structure of the Female Reproduction System

Figure 1.25 shown below illustrates the female reproductive system in humans. Each labelled part has an important function in the process of reproduction.

Figure 1.25 **Female Reproductive System**



Vagina: The vagina is the tube-shaped part of the female reproductive system that receives sperm from the male and acts as the birth canal.

Cervix: The cervix connects the vagina to the uterus.

Uterus: The uterus is the location where the fertilized egg will travel. In the uterus, the fertilized egg will receive nourishment and protection as it develops.

Ovary: The ovary is the primary female reproductive organ. The ovary is the place where a follicle cell will develop into a mature egg cell that is ready to be fertilized by sperm.

Oviduct: The oviduct is the tube connecting the ovaries to the uterus. After a primary oocyte has travelled through the oviduct to the uterus, it will be a mature egg that is ready to be fertilized.

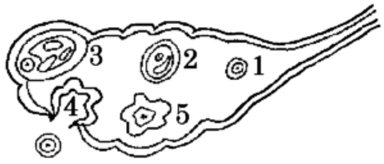
Follicle: The ovary contains many follicles composed of a developing egg surrounded by an outer layer of follicle cells.

The Process of Ovulation

The diagram below is an ovary. The formation of an egg cell is illustrated in the stages numbered from 1 to 5 with stages 4 and 5 illustrating the corpus luteum.

Starting at 1 and going counter-clockwise through the stages of egg cell production, you can see the **follicle** produces an egg cell that breaks through the ovary wall to deposit a mature egg cell into the oviduct. The process of releasing an egg into the oviduct is called **ovulation**.

Figure 1.26 **Ovary**



The **corpus luteum** remains in the ovary, ready to form hormones if a pregnancy begins. If the egg cell is not fertilized, the corpus luteum disappears in about 10 days.

The feathery ends of the oviduct, as well as contractions of the oviduct wall, push the egg into position to be fertilized. The egg can survive for one to two days before it dies and is eliminated. The sperm must encounter the egg during the one to two days for **fertilization** to take place.

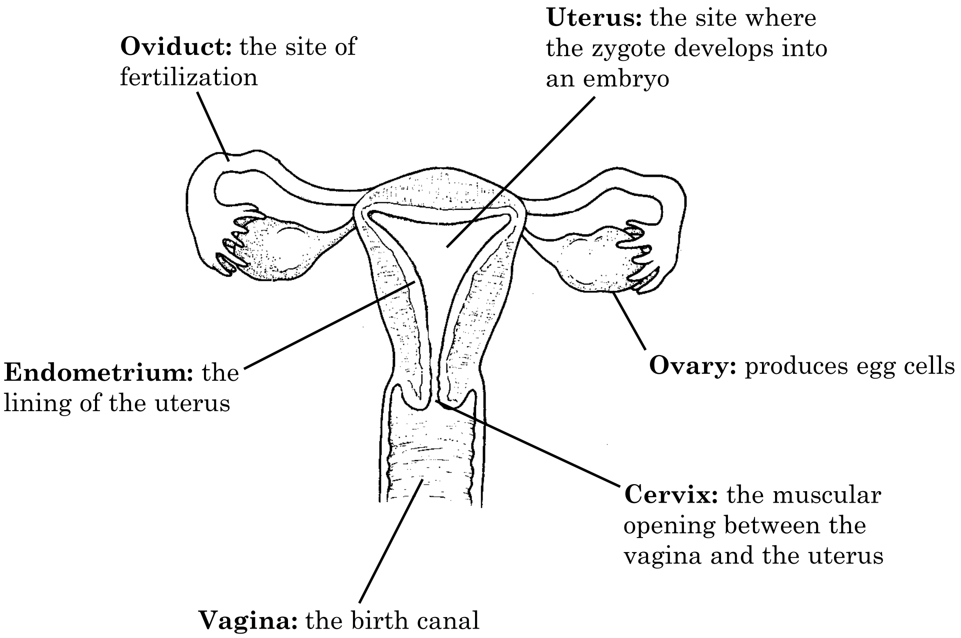
The following website provides a tutorial on fertilization.

- The University of Arizona
  www.biology.arizona.edu/human_bio/problem_sets/Human_Reproduction/02t.html

Fertilization and Formation of a Zygote

Fertilization of the egg takes place in the **oviduct**. Once sperm have been released in the vagina, they travel by moving their tails (flagella) back and forth. Sperm move through the vagina, cervix, uterus, and into the oviduct where they can meet a single egg. Several hundred million sperm are released in the vagina but only several thousand will reach the egg.

Figure 1.27 **Fertilization**



Of the several thousand sperm that reach the oviduct, only one will fertilize the egg. The egg cell is large compared to the sperm. The first sperm to penetrate the cell wall of the egg will trigger a chemical reaction that prevents any other sperm from entering the egg. This way, there can be only one male parent.

Sperm from the male have undergone complete meiosis but the egg cell has only undergone Meiosis I when the female was developing in her mother's womb. The egg cell then completes Meiosis II after the sperm has entered. The sperm and the egg now each have haploid numbers of chromosomes. The two are able to join nuclei and produce a single diploid cell called a zygote that has 23 pairs of chromosomes. Recall that humans have 23 pairs of chromosomes in all cells except sex cells.

Ovulation and Menstrual Cycle

The female reproductive system is more complicated than the male system since females must care for the embryo once the egg has been fertilized.

The human female differs from the male in that she receives all the egg cells **(oocytes)** she will ever have during her embryonic development inside her mother's womb. A female receives around 7 million **follicle cells** between the 14th and 20th week of her development as a fetus. Follicle cells surround oocytes and provide nourishment for them. The number of follicle cells from that moment decrease until her birth where she will have about 2 million and to the time of **puberty** when she will have about 400,000.

The following website provides a tutorial on ovulation.

- The University of Arizona
  www.biology.arizona.edu/human_bio/problem_sets/Human_Reproduction/09t.html

A Description of the Fertilization Site

The fertilized egg is moved into the **uterus** where it is attached to the uterus wall. The uterus wall contains a lining called the **endometrium** that provides nourishment to the developing embryo.

The male sperm has no reproductive cycle. Large numbers of sperm are produced continuously. The female, however, has a cycle called the **menstrual cycle** in which her body prepares the endometrium in four ways:

- building up the endometrium (follicular phase)
- ovulation
- preparing hormonally for pregnancy (luteal phase)
- shedding the endometrium if no pregnancy occurs (menstrual phase)

The menstrual cycle is approximately 28 days in length.

If there is no fertilization and no pregnancy is taking place, the egg cell and the endometrium are discarded through **menstruation**. Menstruation is a flow of liquids that flush out the egg and endometrium that have not been used for embryo development. If a pregnancy has taken place, there is no menstrual flow as the egg is developing into an embryo and the endometrium is needed to sustain the embryo.

Hormones and the Female Reproduction Cycle

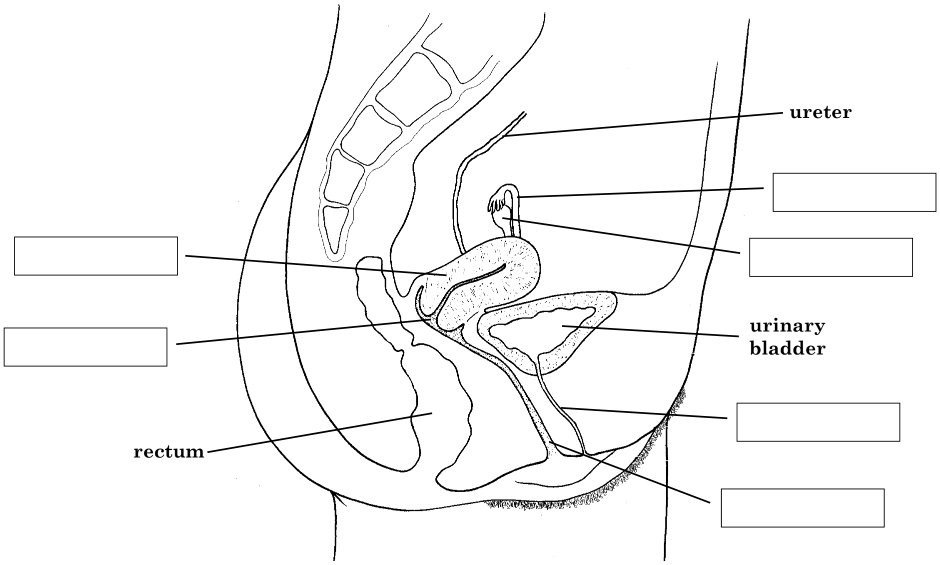
Once the female reaches puberty, the pituitary gland secretes two hormones. These hormones are the same as those for the beginning of male puberty: **FSH** and **LH**. During this time, development of the external and internal reproductive organs takes place as the body prepares for reproduction.

The interaction of hormones in the reproductive cycle for females is described below.

- The pituitary gland secretes FSH into the blood and stimulates follicles to develop in the ovary.
- Follicle cells surrounding the developing oocyte secrete **estrogen**, which is responsible for the thickening of the uterine lining.
- Estrogen travels to the pituitary and causes it to release LH. LH triggers ovulation.
- Following ovulation, follicle cells produce a corpus luteum that secretes increasing amounts of estrogen and **progesterone**.
- As the level of progesterone increases, it travels to the pituitary and signals the pituitary to decrease the production of LH and FSH. The decreasing levels of LH and FSH prevent the production of egg cells until the next cycle when levels of LH and FSH increase again.

Learning Activity 1.8: The Female Reproductive System

1. What is the main sex organ in females?
2. State the two phases of the female reproductive cycle and indicate where they occur.
3. How do the production of sex cells in males and females differ?
4. What two hormones are present in both males and females?
5. What hormone is characteristic of male reproduction and which one is characteristic of the female reproduction cycle?
6. Give a brief description of ovulation.
7. What type of cell reproduction takes place in the zygote once fertilization occurs?
8. How many chromosomes are in each cell of the embryo?
9. Contrast the reproductive function of the human male and female.
10. Fill in the labels for the diagram showing the female reproductive system below.



Check the answer key.

Summary

The reproductive cycle in females consists of two basic stages:

- ovulation, where the ovary prepares the egg for fertilization
- menstruation, where the uterus is prepared to nurture the fertilized egg as it develops into a mature embryo ready for birth

The hormones LH and FSH are the same as those in males but they have a different effect. FSH triggers the development of follicle cells and the production of estrogen. Estrogen stimulates the uterus to thicken the endometrium in preparation for the zygote. Progesterone is produced in the corpus luteum. It also helps produce a thick endometrium and prepares the uterus for an embryo.

LESSON 9: CONCEPTION THROUGH BIRTH

Lesson Focus

After completing this lesson, you will be able to

- ☐ create a timeline showing the stages of human development
- ☐ explain the differences between the terms *zygote*, *embryo*, and *fetus*
- ☐ label a diagram of the stages of human development

Key Words

- zygote
- embryo
- fetus

Online Resources

The following websites provide information about fetal and child development.

- Westside Pregnancy Clinic
  www.wpclinic.org/parenting/fetal-development/first-trimester/
- University of Pennsylvania Health System
  www.med.upenn.edu/meded/public/berp/overview/BV_1.html

Introduction

Now that you are familiar with both male and female reproductive systems, you will investigate the stages of development between the initial formation of a zygote and the birth of a newborn baby.

Fertilization and Formation of a Zygote

The ovary is the primary female reproductive organ. The ovary contains a group of cells called follicles. There are two types of follicle cells:

- one is a reproductive cell that produces the egg
- the others are cells that produce nutrients

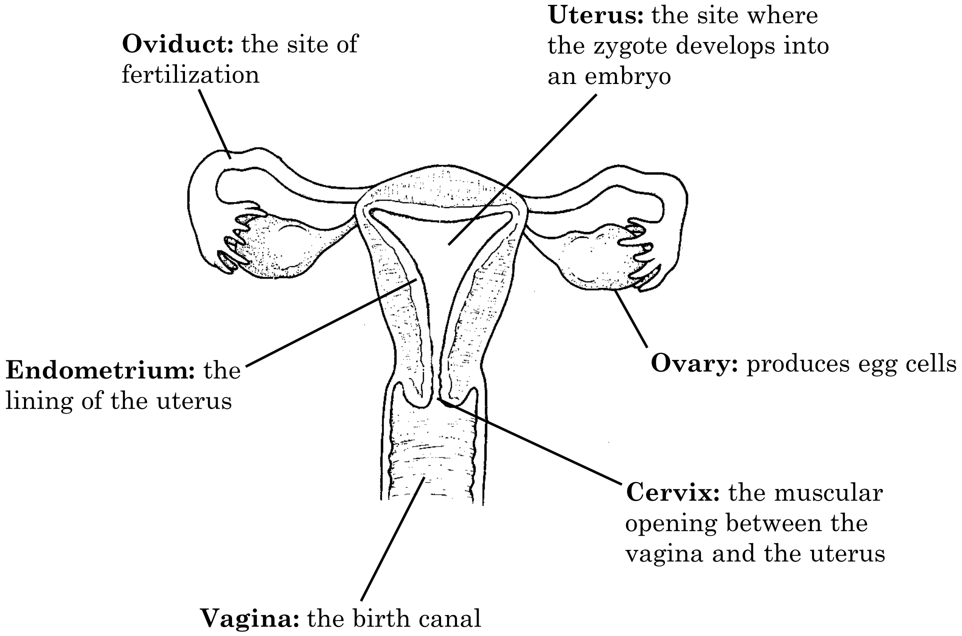
Only one follicle is allowed to reach maturity in a cycle. The other follicles move away and are absorbed in the ovary.

If the egg has been fertilized as it moves from the oviduct to the uterus, it will attach to the thick lining called the endometrium in the uterus. If the egg is not fertilized, the endometrium is shed in a process called menstruation.

Fertilization of the egg takes place in the oviduct. Once sperm have been released in the vagina, they travel by moving their tails (flagella) back and forth. Sperm move through the vagina, cervix, and uterus, into the oviduct where they can meet a single egg. There were several hundred million sperm released in the vagina but only several thousand will reach the egg.

The egg and sperm join nuclei to produce a single diploid cell called a **zygote**. Recall that humans have 23 pairs of chromosomes in all cells except sex cells (sperm and egg).

Figure 1.28 **Fertilization**



Determining Sex

Sperm reach the haploid number of chromosomes through meiosis. Sperm, then, have 23 chromosomes instead of 23 pairs of chromosomes, since meiosis allows each sperm to have half the original number of chromosomes. Of the 23 chromosomes, sperm have one chromosome that determines sex. The chromosome that determines sex can be either X, which produces female offspring, or Y, which produces male offspring. The egg cell has only X chromosomes. Hence the male parent determines the sex of the offspring.

When the sperm and egg unite, the chromosomes will combine to form 23 pairs of chromosomes. Twenty-two pairs determine everything about the offspring but the 23rd pair determines the sex of the offspring. If two X chromosomes combine, the result is a female offspring and if an X combines with a Y chromosome, the offspring is a male. Sex determination takes place at fertilization.

We read in history that females were thought to determine the sex of the offspring. In light of science today, were they correct?

Once the egg has been fertilized and the zygote is formed, there are two stages of development from fertilization to birth.

- **Embryo stage** takes place over the first eight weeks.
- **Fetus stage** takes place from eight weeks to birth.

Embryo Stage

Once fertilization has taken place in the oviduct, the zygote is moved into the uterus and attaches to the endometrium.

Fetus Stage

The developing child will begin to form bone cells around the ninth week of pregnancy or approximately at the end of the first trimester. Once this stage is reached, the child is called a fetus until it is born.

Summary

The development of a single cell zygote to a child born nine months later is a truly awe-inspiring journey. Approximately 40 sets of mitosis produce trillions of cells differentiated into tissues and organs that make a single offspring.

Assignment 1.2: From Conception to Birth (40 marks)

You may wish to work on this assignment with your learning partner.

A woman's time in pregnancy is divided into three trimesters. Write a one-page summary describing, for each trimester,

- the length of time spent in the stage
- the characteristics of the embryo/fetus
- the movement of the embryo/fetus
- the weight and size of the embryo/fetus
- any risks to the embryo/fetus during development

Make use of resources from the library and the Internet to conduct your research. You may also wish to speak with a public health nurse or visit a community health centre for pamphlets or printed information.

You can present your findings as a written report, a poster, or a PowerPoint presentation. Your summary will be assessed using the following rubric:

Content	Length and Style	Sources Used	Grammar, Neatness, and Spelling	Total Marks
30 marks (10 marks x 3 trimesters)	2 marks	4 marks	4 marks	40 marks
For each trimester, describe ■ the length of time the embryo/fetus spends in the stage *(1 mark)* ■ the physical characteristics of the embryo/fetus *(3 marks)* ■ the movement capable by the embryo/fetus *(1 mark)* ■ the weight and size of the embryo/fetus *(2 marks)* ■ any risks to the embryo or fetus during development *(3 marks)*	**Report:** At least 1 typewritten page, double-spaced, using a font no larger than 12. **PowerPoint:** At least 6 slides. Text is in a font and colour that is easy to read. Uses backgrounds, transitions and pictures to enhance the presentation. **Poster:** Clear title and sub-headings. Text is organized into sections. Uses colour and pictures to capture attention.	Include a "Works Cited" page/slide/section at the end of your presentation that details all of your research resources. **Books:** Include the title, author, and publisher. **Internet Resources:** Include the page title, author, and URL. **Interviews:** Include the name, occupation, and place of work of each person you interview.	Half-mark removed for each error.	
/30	**/2**	**/4**	**/4**	**/40**

LESSON 10: SINGLE TRAIT INHERITANCE

Lesson Focus

After completing this lesson, you will be able to

☐ explain the terms *genotype* and *phenotype*, *dominant*, and *recessive*

Key Words

- genotype
- phenotype
- dominant
- recessive

Introduction

You have now reviewed the male and female reproductive systems, as well as the process by which a single-cell zygote develops into a human infant. It is thanks to the combining of sperm and egg gametes that human children are physically unique from their parents. In this lesson, we will look in greater detail at how the physical traits of a child are determined.

Genetics

Genetics is a branch of biology that deals with characteristics that are inherited from one generation to the next. Did anyone ever say that you look just like your grandmother or grandfather? If they did, it's because you have inherited some of their characteristics.

Someone may remark on a characteristic that resembles a member of your family. Inherited characteristics such as looks, functions, or behaviours are called **phenotypes**. The genes making up the chromosomes that demonstrate a characteristic are called **genotypes**. A child has blue eyes. Blue eyes are her phenotype and the genes inherited from her parents that are responsible for her blue eyes are called the genotype.

Every characteristic you have comes from your parents. Your parents could have quite different characteristics and you notice that some characteristics from each parent are part of your makeup. What determines the characteristics that show up in you? Scientists have found that there are two kinds of genes. One type of gene is called recessive and the other type is called dominant. Brown eye colour is a dominant gene and blue eye colour is a recessive gene. If you inherited a blue eye colour gene from one parent and a brown eye colour gene from the other parent, you would have brown eyes. The rule for inherited traits follows:

Whenever a recessive trait combines with a dominant trait,
the dominant trait always shows as the phenotype.

A recessive trait will only show in the offspring when
two recessive traits combine.

A blue-eyed daughter will be born only when both parents give her a blue-eyed gene.

DOMINANT trait + recessive trait = DOMINANT Phenotype

DOMINANT trait + DOMINANT trait = DOMINANT Phenotype

recessive trait + recessive trait = recessive Phenotype

Learning Activity 1.9: Observing Traits

This is a good time to perform some observations.

You can record several easily observed genetic traits in a table. These traits are

- Tongue roll

  Some people can roll their tongue and others cannot. Stick your tongue out and roll it into a tube.

- Thumb

  Some people can bend their thumb backwards and others can only have their thumb remain straight. Spread your hand out as far as you comfortably can. Look at your thumb. Does it remain straight or is the last segment bent way back?

- Earlobe

  Some people have an attached earlobe whereas others have a detached earlobe. Check to see if the bottom of your earlobe is attached to the side of your head.

- Hairline

  Some people have a smooth hairline in front and some have a pointed hairline. Lift the front of your hair and brush it back so you can see the hairline.

continued

Learning Activity 1.9: Observing Traits (continued)

You are given two tables below to fill with data.

In the first table, record data from 10 friends who are not related to you. In the second table, record data that you have gathered from 10 relatives. You may include mother and father, grandmother and grandfather, cousins, and so on.

Table 1
Traits of Friends

Characteristic Traits		**Friends**									
		1	2	3	4	5	6	7	8	9	10
Tongue	Can Roll										
	Cannot Roll										
Thumb	Bent Back										
	Straight										
Earlobe	Attached										
	Detached										
Hairline	Smooth										
	Pointed										

Table 2
Traits of Relatives

Characteristic Traits		**Relatives**									
		1	2	3	4	5	6	7	8	9	10
Tongue	Can Roll										
	Cannot Roll										
Thumb	Bent Back										
	Straight										
Earlobe	Attached										
	Detached										
Hairline	Smooth										
	Pointed										

continued

Learning Activity 1.9: Observing Traits (continued)

Draw a bar graph showing the number of people who can roll their tongue, bend back their thumb, have attached earlobes, and have smooth hairlines. Make one bar graph for your friends that could represent the population as a whole. Draw another bar graph for your family.

Which of the trait possibilities is dominant according to your data? Complete the table below.

Characteristic Traits	Trait Alternatives	Number of Friends	Number of Relatives
Tongue			
Thumb			
Earlobe			
Hairline			

Does your family have a trait that is not as common in the general population? If so, what would be the reason for it?

Were you able to observe any traits other than the ones on your list? Write some of them down and check them in friends and family.

Check the answer key.

Notes

LESSON 11: SINGLE TRAIT INHERITANCE—A CLOSER LOOK

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe how traits are produced in offspring
- ☐ draw Punnett squares to illustrate the transfer of single traits
- ☐ use Punnett squares to predict phenotype and genotype probabilities
- ☐ demonstrate an understanding of the terms *DNA*, *chromosomes*, *genes*, *genotype*, *traits*, *dominant*, *recessive*, and *phenotype* by defining them, describing them, or making a word cycle with them

Key Words

- chromosomes
- genes
- trait
- alleles
- Punnett square
- homozygous
- heterozygous

Online Resources

The following websites provide information about genetics.

This site is a good source for introductory genetics.

- Michael J. Farabee
  http://www2.estrellamountain.edu/faculty/farabee/biobk/BioBookgenintro.html

This site provides a description of Gregor Mendel, the father of genetics.

- Oracle Education Foundation
  http://library.thinkquest.org/19037/idfog.html

Introduction

Previously, you learned that all of your physical traits were inherited from your parents, and that traits are classified as either dominant or recessive. Now it is time to dive deeper into the inner workings of the human body to examine our genes—the tiny building blocks that determine a person's physical traits. We will also discover how, by knowing what genes our parents have, you can predict all the possible traits you can possess.

Genes, Alleles, and Traits

Genes, alleles, and traits are closely related terms and are easily confused.

- **Traits**

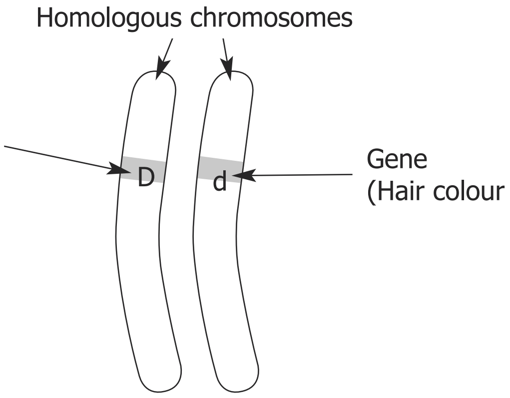
  A trait is a single, observable characteristic of an individual. For example, a trait in an offspring could be dark hair or blue eyes.

- **Genes**

  Genes are a piece of chromosome that contains the code for a certain trait. There are genes for height, weight, eye colour, earlobe attachment, and so on. Every physical characteristic we have is produced by a specific gene in our chromosomes.

Each person carries two genes of a given trait. One gene comes from the mother's egg and one from the father's sperm.

Figure 1.29 **Genes**

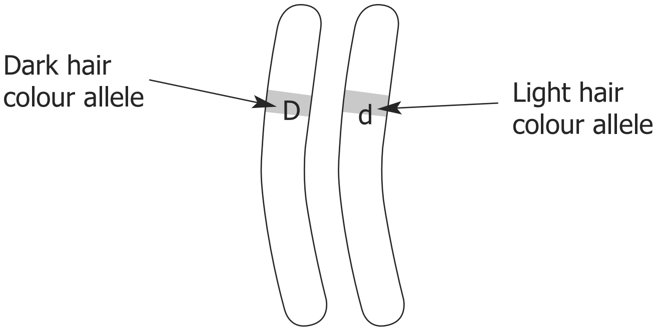


- **Alleles**

  Alleles are the different possible types of a single gene. For example, the gene that determines hair colour has black, brown, blonde, and red alleles. Some alleles are dominant while others are recessive.

  If one of your two paired genes is dominant over the other, the dominant allele will mask the recessive allele. For example, if the mother provides a dark hair-colour allele and the father a light hair-colour allele, the offspring will have dark hair since dark hair colour is dominant.

Figure 1.30 **Alleles**



All of the combined observable characteristics in an individual are called the **phenotype**. The genetic structure creating the characteristics is called the **genotype**.

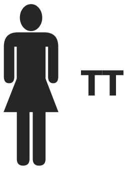
Punnett Squares

The British mathematician/biologist R. C. Punnett developed a method for visually representing the possible combinations of alleles from the parents. It was then possible to predict the possible outcomes of the offspring.

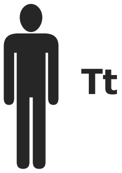
Before taking a closer look at Punnett squares, we will describe the parents more carefully. Parents, both male and female, each have two alleles for any trait due to the 23 **pairs** of chromosomes. Recall that each pair of chromosomes is homologous, that is, they have genes responsible for the same characteristic.

If we were tracking the tallness trait, then we know that each parent has two alleles for tallness, one on each chromosome that contains the tallness gene. There is a dominant allele causing tallness and a recessive allele causing shortness. The easiest way to represent the alleles is to give them a symbol. Usually the symbol for an allele is to give it the first letter of the dominant characteristic—in this case *T* for tallness. The recessive allele is given the lower case letter of the dominant allele—in this case *t* for shortness. A Punnett square assigns two alleles for tallness to each parent and predicts the outcome.

We will assume there are parents who are both tall. The mother is tall with two alleles for tallness. The father is tall but has one tall and one short allele.



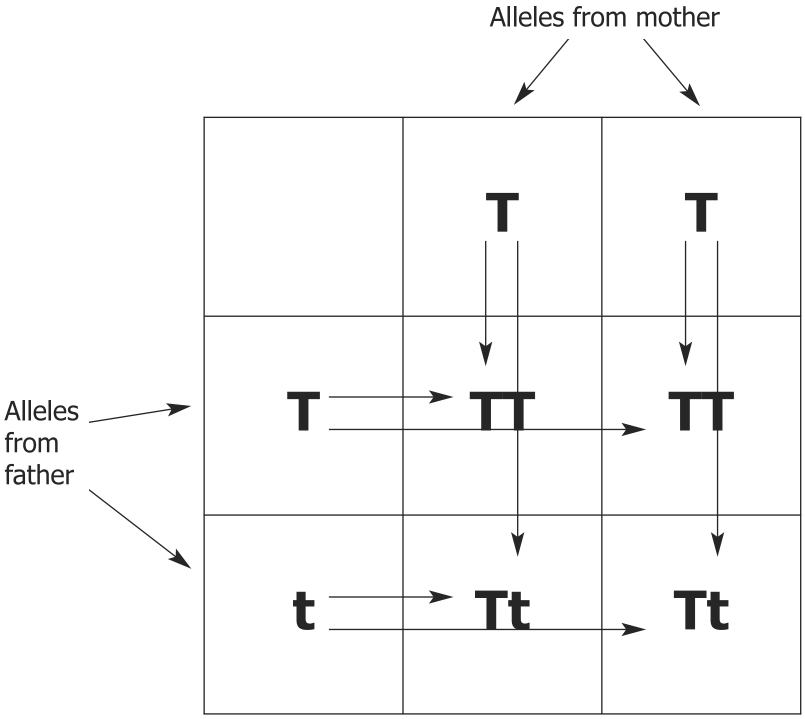
The mother is called **homozygous** since she has two alleles that are the same. The **TT** represents the two dominant allelles for tallness.



The father is called **heterozygous** since he has two different alleles. The **Tt** represents the one dominant (**T**) and one recessive (**t**) allele for tallness.

A Punnett square is shown below.

Figure 1.31 **Punnett Square**



Each parent contributes one allele to form the trait in the offspring.

Notice how gametes from the father combine with gametes from the mother to form offspring with two gametes, one from each parent.

The possible offspring with the tallness trait are shown below.

1. Two homozygous tall **TT**
2. Two heterozygous tall **Tt**

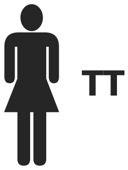
Learning Activity 1.10: Tallness Trait

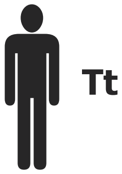
1. How many tall and how many short offspring will there be from these parents?

   Tall ______ Short ______

   You can predict the offspring that come from parents having heterozygous genes.

2. Both parents in the example below are heterozygous tall. Place the gamete symbols in their correct form for the two parents.





3. Place the gametes for the mother on top and for the father on the side of the Punnett square. Fill in the Punnett square.

4. If the parents had four offspring, how many would you expect to be tall? short?

   Tall ______ Short ______

Check the answer key.

You can see from this exercise that Punnett squares are helpful in predicting what characteristics to expect from offspring if you know the parental gametes.

Punnett squares are probability predictors. In the practice Punnett square you have just completed, you are predicting that 75 percent of the offspring are going to be tall. This does not mean that parents with these gametes having four children will produce three tall and one short offspring. It is possible for them to produce two tall and two short, for example. However, with a large sample of families with the same gametes, we would find that very close to 75 percent of the offspring would be tall.

Punnett squares give us three types of information:

- They show us the gametes each parent can produce.
- They show us the genotype combinations that are possible.
- They tell us the probability that a given genotype will occur.

Learning Activity 1.11: Attached/Free Earlobe Trait

Here is another example of a Punnett square where more terminology is included.

The trait is earlobes. Free earlobes (F) are dominant and attached earlobes (f) are recessive.

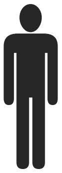
Mother homozygous attached

ff

Phenotype = attached earlobe

Genotype = homozygous attached

Father heterozygous free



Ff

Phenotype = free earlobe

Genotype = heterozygous free

continued

Learning Activity 1.11 (continued)

1. Complete the Punnett square for the parents described on the previous page.

Mother

Father

	f	f
F		
f		

2. Describe the probable phenotypes and genotypes that come from the Punnett square. Indicate the percentage probability of each.
    a. Phenotypes:
    b. Genotypes:

Check the answer key.

Learning Activity 1.12: Genotype and Phenotype

In the following examples dealing with the hair-type gene, G represents the dominant gene for curly hair (which produces curly hair), while g represents the recessive gene for curly hair (which produces straight hair).

Check the answer(s) that correctly complete(s) each statement. Be able to explain your answer.

Part A

An egg cell G and a sperm cell G unite:

1. The genotype of the resulting zygote will be

   ☐ GG ☐ gg ☐ Gg

2. The zygote will be

   ☐ heterozygous ☐ homozygous

3. The resulting human will have the following phenotype:

   ☐ curly hair ☐ straight hair ☐ part curly, part straight

4. The resulting human will be able to produce the following gametes:

   ☐ G ☐ g ☐ G or g

An egg cell g and a sperm cell g unite:

5. The genotype of the resulting zygote will be

   ☐ GG ☐ gg ☐ Gg

6. The zygote will be

   ☐ heterozygous ☐ homozygous

7. The resulting human will have the following phenotype:

   ☐ curly hair ☐ straight hair ☐ part curly, part straight

continued

Learning Activity 1.12 (continued)

8. The resulting human will be able to produce the following gametes:

   ☐ G ☐ g ☐ G or g

An egg cell G and a sperm cell g unite:

9. The genotype of the resulting zygote will be

   ☐ GG ☐ gg ☐ Gg

10. The zygote will be

    ☐ heterozygous ☐ homozygous

11. The resulting human will have the following phenotype:

    ☐ curly hair ☐ straight hair ☐ part curly, part straight

12. The resulting human will be able to produce the following gametes:

    ☐ G ☐ g ☐ G or g

An egg cell g and a sperm cell G unite:

13. The genotype of the resulting zygote will be

    ☐ GG ☐ gg ☐ Gg

14. The zygote will be

    ☐ heterozygous ☐ homozygous

15. The resulting human will have the following phenotype:

    ☐ curly hair ☐ straight hair ☐ part curly, part straight

16. The resulting human will be able to produce the following gametes:

    ☐ G ☐ g ☐ G or g

continued

Learning Activity 1.12 (continued)

Part B

State your answer to the following questions in the form of a fraction or a percentage.

17. If a father (GG) and a mother (gg) have children, what will be the expected proportion of the following genotypes?

    GG ______ gg ______ Gg ______

18. If a father (gg) and a mother (GG) have children, what will be the expected proportion of the following genotypes?

    GG ______ gg ______ Gg ______

19. If a father (Gg) and a mother (GG) have children, what will be the expected proportion of the following genotypes?

    GG ______ gg ______ Gg ______

20. If a father (Gg) and a mother (Gg) have children, what will be the expected proportion of the following genotypes?

    GG ______ gg ______ Gg ______

Check the answer key.

Summary

Each parent contributes one gene to their offspring. Each trait comes from a single gene. Dominant genes will mask recessive genes.

The probability of traits showing up in offspring can be represented using Punnett squares. Punnett squares allow the prediction of the phenotypes and genotypes for any trait.

Notes

LESSON 12: INHERITANCE OF SEX-LINKED TRAITS

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe the probable offspring phenotypes of parents having sex-linked traits
- ☐ use Punnett squares to predict the genotypes from parents with sex-linked diseases
- ☐ use a simple pedigree to assess ancestral genotype
- ☐ use a simple pedigree to predict offspring phenotype and genotype

Key Words

- sex-linked trait
- sex chromosomes
- pedigrees
- autosomal pedigrees
- sex-linked pedigrees

Online Resources

The following websites provides information about genetics.

This site provides information on using Punnett squares.

- Oracle Education Foundation
  http://library.thinkquest.org/19037/heredity.html

This site provides information on creating pedigrees and includes a good description of pedigrees and their function.

- University of Illinois at Chicago
  www.uic.edu/classes/bms/bms655/lesson3.html#Sample

This site provides definitions of genotype, phenotype, trait, and genetic code.

- John Blamire
  www.brooklyn.cuny.edu/bc/ahp/BioInfo/SD.Geno.HP.html

This is a very good site on sex-linked inheritance. A tutorial is based on multiple choice questions. If you give an incorrect answer, a tutorial automatically appears.

- University of Arizona
  www.biology.arizona.edu/mendelian_genetics/mendelian_genetics.html

Introduction

This lesson will continue our exploration of genes and inheritance, but now we will narrow our focus onto the two specific chromosomes that determine whether a person is male or female. Depending on the genetic cross, these chromosomes can also carry disorders such as colour-blindness and baldness. You will also learn how to construct a type of family tree called a pedigree to track certain traits back through your ancestors.

Sex-Linked Traits

Sex-linked traits are traits attached to the **sex chromosomes** in a female or male. Most sex-linked traits are associated with the X chromosome.

Let's review how sex-determining chromosomes function.

Around 1890, scientists discovered that chromosomes in cells from males and females were identical except for one pair. This pair of chromosomes are known as sex chromosomes.

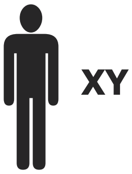
In addition to carrying genes that determine sex, the X and Y chromosomes carry genes that establish other traits. Traits determined by genes on the **sex chromosomes** are called sex-linked.

Some sex-linked traits that show up as disorders are hemophilia and colour-blindness.

Some other important points include the following:

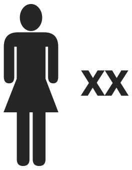
- Males have one X and one Y chromosome.
- Females have two X chromosomes.
- Fathers can pass on X-linked alleles to daughters only, not to sons (fathers pass the Y chromosome to sons).
- Males always receive their X chromosome from the mother.
- Fathers cannot pass X-linked alleles to their sons.
- Mothers can pass X-linked alleles to daughters and sons.
- Females receive two X chromosomes—one from the mother and one from the father.

Males and Sex-Linked Traits



Males receive X chromosomes from only their mother, never from their father. Sex-linked traits are usually attached to the X chromosome. This means any sex-linked trait attached to the X chromosome will always come from the mother. A male has one X chromosome only. If he receives one chromosome from the mother with a sex-linked allele on it, he will demonstrate that trait. Sex-linked diseases in a male are inherited from the mother.

Females and Sex-Linked Traits



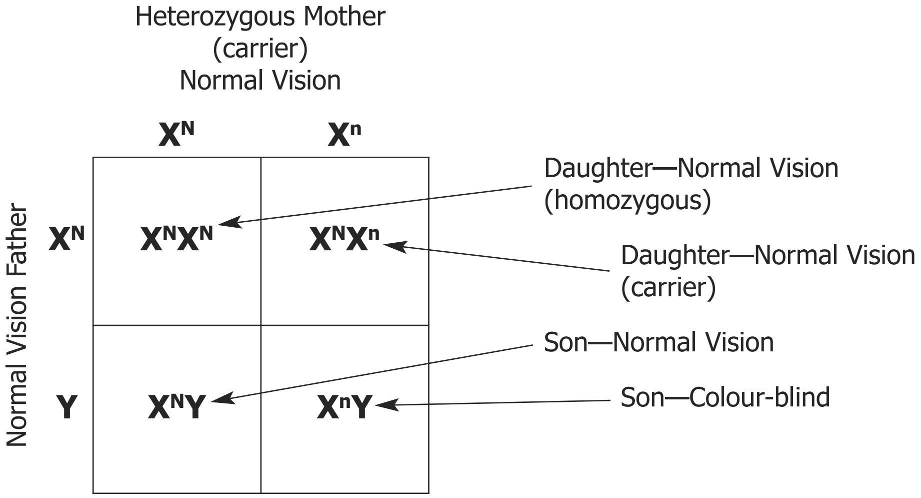
Females receive X chromosomes from both parents. If a female is to demonstrate a recessive sex-linked trait, she must have two recessive alleles attached to both X chromosomes. If a female receives one recessive sex-linked allele, she is a carrier and will give one-half of her sons the sex-linked trait. She will also give one-half of her daughters the sex-linked allele, but they will be carriers and will not demonstrate the trait.

Punnett Squares and Sex-Linked Traits

This is an opportunity to look at some Punnett squares to illustrate possible outcomes of sex-linked traits.

In this case there is a sex-linked allele for colour-blindness. Normal vision (N) is dominant and colour-blindness (n) is recessive.

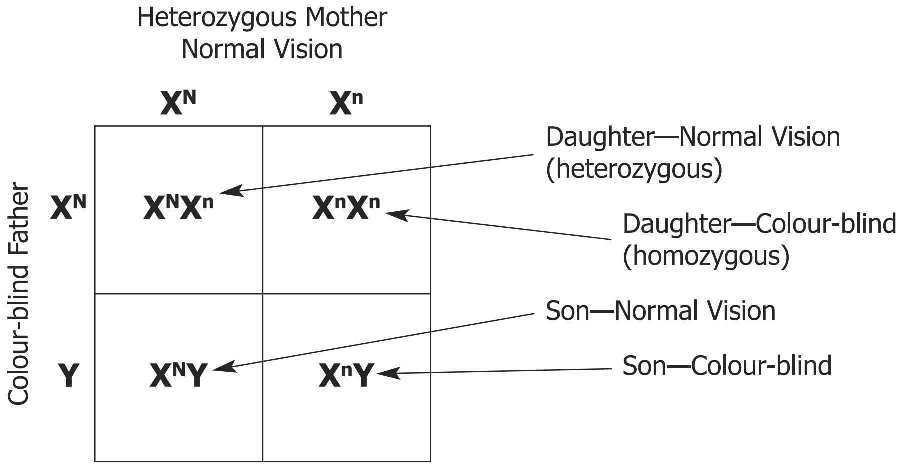
When we are talking about sex-linked traits, it is useful to mark both the chromosome (X or Y) and the allele (N or n). For example, a female that is homozygous for normal vision would be represented as X^NX^N and a male who is colour-blind would be represented as X^nY (we do not need to refer to him has homozygous or heterozygous since the gene is only carried on one chromosome, the X).



The heterozygous mother who does not exhibit colour-blindness has a 50 percent chance of producing a colour-blind son and zero chance of producing a colour-blind daughter.

The homozygous daughter will not have any colour-blind offspring if she has children with a normal-vision male. The heterozygous daughter will produce offspring with the same results as the mother, unless the father of her children is colour-blind.

What kind of offspring result from a colour-blind father and heterozygous normal-vision mother?



The colour-blind father has a 25 percent chance of producing a colour blind daughter and a 25 percent chance of producing a colour-blind son. If the colour-blind daughter now married a colour-blind male, the offspring would have 100 percent colour-blindness.

The odds of having a colour-blind female and a colour-blind male producing offspring are low in the general population. If, however, there were significant inbreeding, that is, if relatives with a sex-linked disease intermarried, then a problem would likely persist in the population.

An example of genetic diseases and sex linkage can be seen in European aristocracy. Royalty knew no national boundaries in Europe. Intermarriage among nations was so common that a Russian prince could have a genetic background that was mostly British.

Pedigrees

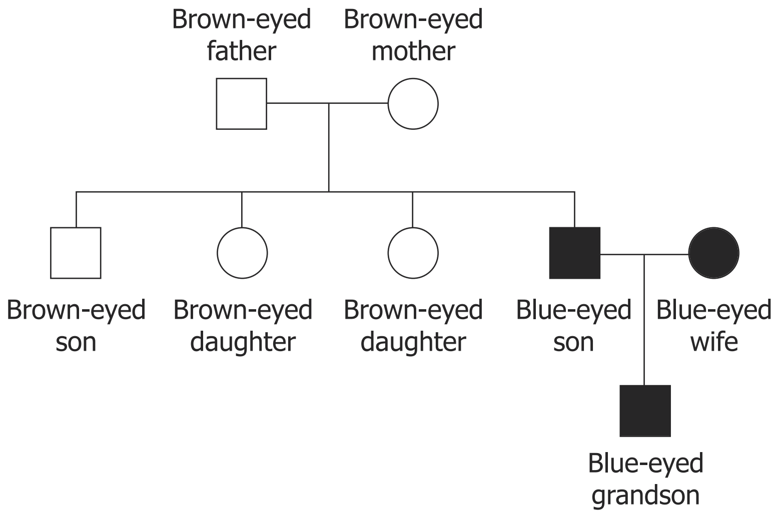
A pedigree is a diagram that shows the presence or absence of a selected trait in each member of a family. A pedigree traces phenotypes (observable traits), and uses the information gathered to predict individual genotypes (the genes that produced the traits).

Symbols can be used to represent female and male ancestors. Symbols are shaded when the trait being studied is observed in an individual. Traits shown by the offspring help determine the parental genotype.

□	Brown-eyes male
■	Blue-eyed male
○	Brown-eyed female
●	Blue-eyed female

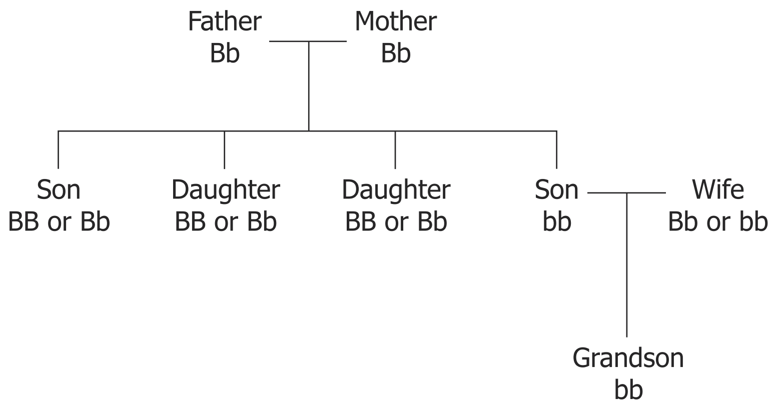
For this example, we will follow eye colour through two generations. We will assume two brown-eyed parents produced four offspring.

Figure 1.32 **Autosomal Pedigree**



Can you predict the genotypes of these individuals?

Figure 1.33 **Genotypes**



There are several pieces of information that relate to pedigrees.

- The genetic information about ancestors is determined through their offspring. The genetic information about the parents in this example can only be obtained through their children and grandchildren.
- We only know the phenotype and must interpret traits in the offspring to derive the genotype.
- There are two types of pedigrees:
  - **Autosomal** pedigrees

    These pedigrees are ones that demonstrate a trait that is not attached to a sex (X,Y) chromosome. The example on the previous page is an autosomal pedigree.

    If an offspring demonstrates a recessive trait, then both parents must have at least one recessive allele. This means the parents can be either homozygous recessive or heterozygous.

    If the offspring demonstrates a dominant trait, then at least one of the parents must have the dominant allele. The parent can be either homozygous dominant or heterozygous.

    If both parents are recessive, all the offspring will be recessive.
  - **Sex-linked** pedigrees

    A common sex-linked pedigree is the one for hemophilia. Recall that most sex-linked traits are inherited through the allele located on the X chromosome, as is the case for hemophilia.

    A female who is heterozygous for the sex-linked trait is called a carrier and is given the symbol ◐.

We will not study sex-linked pedigrees any further in this lesson except to note that a female can be a carrier without displaying the trait and the pedigree can be used to indicate what probability the offspring has of inheriting a genetic disorder.

Learning Activity 1.13: Punnett Squares and Pedigrees

1. There is a sex-linked condition called Mendelism that drives its victims to an unreasonable desire to construct Punnett squares. There is a sex-linked allele where normal (M) is dominant and Mendelism (m) is recessive. The mother X^MX^m and father X^MY have the shown sex-linked alleles. Use the information to answer the following questions.
    a. Describe the phenotype and genotype of the mother and father.
    b. Use a Punnett square to show the probable offspring.
    c. State the phenotype and genotype of each possible offspring.
    d. Is there a possibility that any female offspring could be a carrier?
    e. Is there any possibility of a male compulsive Punnett square constructor?
2. Use the eye colour pedigree example in the lesson to answer the following questions.
    a. State the genotype for
        i. mother and father
        ii. children
        iii. grandchild
    b. What are the phenotypes for the children?
    c. Draw a Punnett square for the possible offspring of a heterogenous brown-eyed female in the second generation and a blue-eyed male.

Check the answer key.

Summary

Sex-linked traits are produced by alleles attached to the X sex chromosome. Some sex-linked traits include colour-blindness and hemophilia. Sex-linked diseases and disorders have a greater chance of affecting the male offspring since males have only one X chromosome whereas females have two X chromosomes. A recessive gene for colour-blindness on a male X chromosome will leave him colour-blind, but a female would require two recessive alleles to produce the trait.

Pedigrees are tables that provide information about ancestral phenotypes and that can provide some information about the phenotypes and even genotypes that are possible in a current generation.

Notes

LESSON 13: SEX-LINKED TRAITS AND YOUR PEDIGREE

Lesson Focus

After completing this lesson, you will be able to

☐ use a pedigree to track probable genotypes in ancestors and predict possible genotypes in offspring

Key Words

- sex-linked trait

Online Resources

The following websites provide information about sex-linked traits and pedigree.

This site provides information about bleeding disorders and gene therapy.

- National Hemophilia Foundation
  http://www.hemophilia.org/

This website deals with pedigrees and includes some challenging activities.

- Oracle Education Foundation
  http://library.thinkquest.org/3037/pedigree.htm

Introduction

Sex-linked traits are usually carried on the X sex chromosome. A **sex-linked trait** is a recessive trait that shows up more often in men than in women.

Hemophilia is an inherited disease of the blood. Affected persons do not have the ability to form blood clots in the way that normal people do. The letter H represents the dominant, normal gene. The recessive gene that causes hemophilia is represented by the letter h.

How is the trait inherited? Is it a sex-linked genetic disease or not?

If it is sex-linked, the gene is located on the X chromosome. If it is not sex-linked, the gene is located on a pair of chromosomes other than the sex chromosomes.

Learning Activity 1.14: Is it sex-linked?

This activity will demonstrate the odds of a disease occurring when it is considered to be sex-linked and when it is considered not to be sex-linked.

Materials

- masking tape
- four pennies
- pen

Procedure

Part 1: Trait is sex-linked

Genes for sex-linked traits are located on the X chromosome. A heterozygous female ($X^H X^h$) has a 50/50 chance that her egg cells will receive either an X^H or an X^h during meiosis. Normal males have the genotype X^HY. The chances that their sperm cells will receive either X^H or Y during meiosis are 50/50. The offspring of the cross between a heterozygous female and a normal male can be determined by coin tossing.

continued

- Put tape on two pennies.
- Mark one penny to represent the heterozygous female. This means mark one side of the penny X^H and the other side of the penny X^h.
- Mark the second penny to represent the normal male. This means mark one side of the second penny X^H and the other side of the penny Y.
- Toss both pennies together 50 times. Record the combination that results after each toss in the chart below (Chart #1).
- Total the results of each genotype and record them in the table.

Chart #1—Results If the Trait Is Sex-Linked

Offspring Phenotype	Offspring Genotype	Result of Each Toss	Totals Observed
Normal Female	X^HX^H or X^HX^h		
Female with Hemophilia	X^hX^h		
Normal Male	X^HY		
Male with Hemophilia	X^hY		

Part 2: Trait is not sex-linked

If the trait is not sex-linked, the genes for hemophilia are not located on the sex chromosomes. This means that there are two sets of chromosomes involved—one set for determining the sex of the offspring and another set involved in determining if the offspring will have hemophilia or not.

Four coins are needed to represent the two pairs of chromosomes. We will assume that both parents are heterozygous, and have the genotypes XXHh (female) and XYHh (male).

continued

Learning Activity 1.14 (continued)

- Put tape on all four pennies.
- Mark two pennies to represent each parent's sex chromosomes. The female should have both sides labeled X, and the male should have one side X and one side Y.
- Mark the third and fourth pennies to represent each parent's hemophilia-determining chromosome. In this test, both male and female will be heterozygous. Mark one side of each coin as H and the other as h.
- Toss all four pennies together 50 times. Record the combinations that result after each toss in the chart below (Chart #2).
- Total the results of each genotype and record them in the table.

Chart #2—Results If the Trait Is Not Sex-Linked

Offspring Phenotype	Offspring Genotype	Result of Each Toss	Totals Observed
Normal Female	XXHH or XXHh		
Female with Hemophilia	XXhh		
Normal Male	XYHH or XYHh		
Male with Hemophilia	XYhh		

Use the information from your tosses to answer the questions below.

1. If a recessive trait is sex-linked, how many genes must a male have to inherit it? a female?
2. If a recessive trait is not sex-linked, how many genes must a male have to inherit it? a female?
3. If the father is normal and the mother is heterozygous, how many normal female children are observed when the trait is sex-linked?
4. If both parents are heterozygous, how many normal female children are observed if the trait is not sex-linked?

continued

Learning Activity 1.14 (continued)

5. If both parents are heterozygous, how many female children with the disease (recessive trait) are observed if the trait is not sex-linked?
6. If the mother is heterozygous and the father is normal, how many female children with the disease (recessive trait) are observed if the trait is sex-linked?
7. Which inheritance pattern results in no females with the disease?
8. If the father is normal and the mother is heterozygous, how many normal male children are observed when the trait is sex-linked?
9. If both parents are heterozygous, how many normal male children are observed if the trait is not sex-linked?
10. If both parents are heterozygous, how many male children with the disease are observed if the trait is not sex-linked?
11. If the mother is heterozygous and the father is normal, how many male children with the disease are observed if the trait is sex-linked?
12. Which inheritance pattern provides equal numbers of normal male children and male children with the disease?
13. Write a short paragraph that explains how sex-linked traits are different from other inherited traits. Be sure to include such words as *genotype, phenotype, dominant, recessive, and carrier*.

Check the answer key.

Notes

LESSON 14: GENETIC MUTATION—CHOICES AND ENVIRONMENTAL FACTORS

Lesson Focus

After completing this lesson, you will be able to

- ☐ identify which substances may cause genetic mutations
- ☐ identify which substances may cause changes in development
- ☐ identify the environmental factors and individual choices over which you have some control
- ☐ describe methods to reduce the risk of genetic mutations or changes in development

Key Words

- mutation
- chromosome mutation
- gene mutation
- carcinogen
- mutagen

Online Resources

Online resources are shown throughout the lesson.

Introduction

You have learned in the section on reproduction that humans reproduce sexually with both parents contributing a haploid set of 23 chromosomes through meiosis. Together, both parents provide 23 pairs of chromosomes.

On each chromosome are many genes. Each gene is responsible for one trait in the offspring. Recall that the 23 pairs of chromosomes are homologous. Two chromosomes produce similar characteristics. This means, in turn, that two genes are responsible for each characteristic in the offspring.

Genes are either dominant or recessive. Using an example, a curly hair gene (C) is dominant and straight hair gene (c) is recessive. An offspring receiving a dominant gene for curly hair from one parent and a recessive gene for straight hair from another parent will exhibit the curly hair trait. The dominant gene trait will mask the recessive gene trait.

When everything is working normally, one generation follows the next with inherited traits appearing in the phenotype.

Sometimes something goes wrong and the offspring show unexpected traits. Where do these variations come from?

First, recall that we have two kinds of reproduction taking place. Sexual reproduction is responsible for creating the next generation. Meiosis reduces the number of chromosomes from each parent from 46 chromosomes (or 23 pairs) to 23 individual chromosomes. In this way, the offspring will also have 23 pairs—23 chromosomes from each parent. Our bodies also use asexual reproduction to produce new cells as soon as the sperm and egg unite. We also use mitosis to produce new cells for repair and replacement in our bodies.

Whenever an offspring has an unexpected trait caused by an abnormality in meiosis or mitosis, we can say there has been a mutation in the gene responsible for the trait in the individual or the function of the cell. Mutations to somatic (non-reproductive) cells are not inherited by offspring.

The reproductive process, either meiosis or mitosis, is not flawless. There are many opportunities for errors to occur in both processes. A list of genetic mutations is shown below.

A **chromosome mutation** is a major change occurring in one or more of the chromosomes, or in the number of chromosomes.

A **gene mutation** is an abnormal change in a gene, such as losing or altering part of its structure. They can result in single gene disorders or multifactorial disorders.

Chromosome Mutations

Chromosome mutations are the most common form of genetic mutation. During meiosis, chromosomes or parts of chromosomes can be lost, changed, or mixed up. Since a chromosome is made of many genes, a chromosome mutation can have a large impact on the offspring. Down syndrome and Turner syndrome are both examples of the effects of chromosome mutation.

Gene Mutations

Single Gene Disorders

Single gene disorders are caused by a single gene losing or altering part of its structure by mutation. An example of a single gene disorder is sickle-cell anemia. This mutation causes blood cells to look like a sickle rather than the normal doughnut-without-a-hole shape of a blood cell. Cystic fibrosis and Huntington's disease are also single gene disorders.

Multifactorial Disorders

Multifactorial disorders result from mutations in several genes, often combined with environmental causes. The complicated origins of these diseases make them difficult to study and to treat. Heart disorder, diabetes, and cancer are examples of this type of disorder.

Cancer is a disease that arises from a combination of factors. One cause of cancer is an inherited gene mutation. Another cause of cancer occurs after birth from a combination of factors, such as overexposure to ultraviolet light, certain chemicals, or viruses. Random genetic mutation or the aging process can also lead to cancer.

Any cancer involves a mutation that interferes with a cell's mitosis. A normal cell has detectors that indicate when a cell should stop replicating, when it is in contact with other cells and should stop, or when it is occupying space that doesn't belong to it. When these signals fail to work properly, the cell is in danger of reproducing itself without stopping, causing a tumor. Chemicals that cause cancer are called carcinogens.

Other diseases called diabetes, Tourette syndrome, and lupus are a result of more than one factor giving rise to an illness. All of theses diseases involve a genetic mutation.

It may seem that we are surrounded by genetic mutations. Genetic mutations are common, but serious mutations are often expelled by the body and never show up. Sexual reproduction also has the ability to deal with mutations as they are usually recessive and do not show up in the offspring.

The medical and scientific community is researching ways of dealing with genetic diseases when they do manifest themselves. In recent years, there have been many advances in the treatment of genetic mutations.

Environmental Factors

Genetic mutations can be the result of an environmental impact. There are different types of mutagens (mutation-causing chemicals) which are capable of altering the genetic code. A list of some mutagens is shown below.

- ultraviolet/radiation overexposure
- toxins
- carcinogens
- food additives
- hormone mimics
- pollution
- pesticides

Lifestyle

There are some lifestyle decisions that can have an impact on genetic mutation. Some of the factors that have been listed as environmental can also be listed as lifestyle

One lifestyle choice that can have an extreme impact on the development of a fetus is a mother's use of alcohol during her pregnancy. Fetal alcohol spectrum disorder (FASD) is a lifelong disease that cannot be reversed. The damage and effects of FASD are often unpredictable and devastating for those who are alcohol-affected, and those who must care for them.

What advice about FAS would you give a sexually active young person? How would you present your advice so that he or she would understand the impact he or she has on a child that could be born? Write a brief message to that person—boy or girl—explaining his or her responsibility to the unborn child.

The following websites provides information about FASD.

- Nemours Foundation
  http://kidshealth.org/parent/medical/brain/fas.html
- Fasworld
  www.fasworld.com/aboutfasd.asp

Learning Activity 1.15: Mutation Situation

Included below are various imaginary scenarios about accidental mutations. None of these situations could really happen, but they are provided so you can think about the possible consequences of each situation.

Scenario 1

Manon regularly visits tanning salons. She does not realize that excess exposure to ultraviolet rays has caused a mutation in one of the cells of her big toe. The modified gene produces a tendency towards skin rashes on her foot.

- Is Manon in danger?
- Will she have problems?
- If she gives birth to a baby in a few months, will her child have these skin rashes? Explain.

Scenario 2

Patrick's dentist forgot to dress him in a lead apron before giving him an X-ray. Unfortunately, the X-ray irradiated one of the chromosomes in the germinal cells of his testicles (the cells that produce sperm). This resulted in a mutation that caused his son to have a nose with three nostrils. Also, the water in which he liked to swim contained a mutagenic pesticide that changed the cells in his lungs, causing Patrick to develop asthma. Five years later, Patrick wonders if his children will also be sick.

continued

Learning Activity 1.15 (continued)

- Will Patrick's children also be asthmatic?
- What kind of problems do his children risk having? Why?
- Can Patrick prevent having children with three nostrils? How could this mutation be an advantage to his children?

Scenario 3

Rebecca has been pregnant for three months. Her fetus's cells have begun to differentiate and its brain is in full development. Rebecca eats too much meat that contains genetically modified preservatives. These preservatives circulate in her bloodstream, causing a mutation of nervous cells that provide both Rebecca and her fetus with the potential for extraordinary musical talent. Thirty years later, Rebecca's child, Peter, is internationally renowned, is married, and has many children.

- Will Peter's children become musically talented as well? Explain.
- Will his children necessarily have little musical talent? Explain.
- Is there a way to produce offspring who would have Peter's musical mutation?

Scenario 4

Freddy the frog is lazy and always hungry. His diet has many deficiencies, so much so that he is lacking ingredients for the proper mitosis of his germinal cells. Freddy does not realize that one of his sperm cells contains a gene that produces wings and that he has fertilized an ovule that also contains a bizarre mutation that produces antennae.

- Will the flying frog with antennae also be lazy?
- Will the frog be able to feed more easily than Freddy?
- Will Freddy produce more flying frogs with antennae?

Scenario 5

Yok and Yik come from the same zygote. They are twins who are experiencing the effects of a drug taken by their mother during an emergency operation while she was pregnant. In Yok's body, the drug caused a mutation in her gland cells, which provoked an overproduction of growth hormones. In Yik's body, the same gene is subjected to this mutation, but only in the ovules she already has.

continued

Learning Activity 1.15 (continued)

- Are Yik and Yok identical twins?
- At birth, Yok is twice as heavy as Yik. Why?
- Will Yok's children be bigger than Yik's? Explain

Check the answer key.

Summary

Mutations are abnormal changes to our genes or chromosomes, sometimes resulting in harmful disorders such as sickle-cell anemia, fetal alcohol syndrome and cancer. They can be the result of a single gene being altered (gene mutation) or entire chromosomes changing (chromosomal mutation).

Mutations are caused by factors in our environments such as overexposure to sunlight, excessive chemicals in our foods, and pesticides. Many mutations are due to lifestyle choices, such as drinking alcohol during pregnancy, and can be avoided or reduced by our personal decisions.

Any mutation of somatic (body) cells can have serious consequences for the individual. A mutation in a sex cell can have consequences for future generations since the mutation can be passed on to the offspring.

Notes

Assignment 1.3: Mutagens Investigation (24 marks)

Pick any two of the mutagens in the following list. Research what they are, and the possible mutations they can cause in humans. Be sure to find out whether these mutagens are environmental, lifestyle-based, or both. Finally, describe how you can avoid or reduce exposure to the mutagen.

- ultraviolet light/radiation exposure
- toxins
- carcinogens
- hormones mimics
- pollution
- pesticides
- food additives

You can present your findings as a written report, a poster, or a PowerPoint presentation. Your assignment will be assessed using the following rubric:

Content	Length and Style	Sources Used	Grammar, Neatness, and Spelling	Total Marks
16 marks (8 marks x 2 mutagens)	2 marks	3 marks	3 marks	24 marks
For each selection, ■ Define the mutagen. What is it? *(2 marks)* ■ Describe how it affects human health and reproduction. *(3 marks)* ■ Classify the mutagen as environmental, lifestyle-based, or both. *(1 mark)* ■ Explain how people can avoid or reduce exposure to the mutagen. *(2 marks)*	**Report:** At least 1 typewritten page, double-spaced, using a font no larger than 12. **PowerPoint:** At least 6 slides. Text is in a font and colour that is easy to read. Uses backgrounds, transitions and pictures to enhance the presentation. **Poster:** Clear title and sub-headings. Text is organized into sections. Uses colour and pictures to capture attention.	Include a "Works Cited" page/slide/section at the end of your presentation that details all of your research resources. **Books:** Include the title, author, and publisher. **Internet Resources:** Include the page title, author, and URL. **Interviews:** Include the name, occupation, and place of work of each person you interview.	Half-mark removed for each error.	
/16	**/2**	**/3**	**/3**	**/24**

Lesson 15: Canadian and International Contributions to Genetics and Reproduction

Lesson Focus

After completing this lesson, you will be able to

☐ describe some areas of genetic and reproductive study where Canadians are involved

Key Words

- in vitro fertilization (IVF)
- embryo transfer
- fertility drugs
- human genome project
- genome
- cystic fibrosis
- genetic engineering
- genetic counselling
- gene therapy

Online Resources

The following website provides information about the Human Genome Project.

- U.S. Department of Energy Genome Programs
  www.ornl.gov/sci/techresources/Human-Genome/education/students.shtml

Introduction

Technology has had a long history and a large impact on human health. Crutches and splints have long been used for helping people who have broken bones or a disorder in their legs. Eyeglasses and dental fillings have also been of great benefit. At the beginning of the twentieth century, the impact of technology and health care increased greatly to the point where we enjoy the benefits of knowledge and technology as no one before us has.

One area of recent significant growth is reproductive and genetic technology.

Reproductive Technology

Reproductive technology has benefited couples that have wanted a child but have been unable to conceive. There are several reasons that can account for this problem:

- lack of sperm in the male
- blocked oviducts in the female
- lack of proper hormones
- improper functioning of the woman's follicles

The prospective parents have an option today of seeking medical assistance for this problem. Some of the strategies employed by the medical profession include the following:

- **In Vitro Fertilization (IVF) and Embryo Transfer**

The following website provides an example of the care that is taken in the preparation and counselling of prospective parents.

- Ottawa Fertility Centre
  www.conceive.ca/index.php

In vitro is Latin for "in glass" or artificial. **In vitro fertilization** refers to the placing of the egg and sperm in an artificial environment. From this came the term "test tube baby." The first "test tube baby" was Louise Brown, born in 1978.

Eggs are removed from the mother or a donor after hormones have stimulated the ovary. A laparoscope is the tool used by a physician to remove the eggs. A donor can be used if the woman wanting the child is unable to produce eggs.

The egg and sperm are collected outside the parents' bodies and combined in the laboratory where fertilization takes place. Later, the fertilized eggs are returned to the uterus where it is hoped the fertilized egg will continue to grow.

Embryo transfer can be used if the woman who would be the natural mother is unable to have the fertilized egg placed in her uterus. In these cases, a surrogate mother is chosen to receive the fertilized egg and take the embryo/fetus to term.

We have all heard of cases where the surrogate mother finds it difficult to release the baby to its parents, and legal battles follow. This is a classic example of how technology can create moral, emotional, and legal difficulties that never existed before. Fertility clinics are addressing these issues as our understanding of the emotional impact these issues have on everyone involved becomes more complete.

■ Fertility Drugs

Fertility drugs are used as a first step for women who are experiencing difficulty becoming pregnant. There are many drugs, but their primary function is to stimulate ovulation in the female in order that sperm from the male can fertilize the egg and produce offspring.

■ Artificial Insemination

The following website provides a complete description of artificial insemination.

- About.com
  http://infertility.about.com/od/infertilitytreatments/a/what_is_IUI.htm

This method of fertilizing the egg takes sperm from the male. The sperm is then injected into the female using a syringe and placing it in the uterus right next to the egg. Artificial insemination has been used with animals since the early twentieth century.

The reproductive technologies described in this section are attempts to increase the possibility of pregnancy when natural methods have failed. Some of the methods seem as if they would only slightly increase the likelihood of a pregnancy, but sometimes this is all that is required.

Technological Development in Genetics

Cord Blood Donation

The blood that is found in the umbilical cord contains stem cells (unspecialized cells that can specialize and be used for many purposes). If this blood is donated after the birth of the baby, these stem cells can be saved for later use by the baby, a sibling, or another family member. Some benefits of using the stem cells found from the cord blood include regrowth of heart and lung tissue, cancer treatment, and treatment for Parkinson's disease and Alzheimer's disease.

The Human Genome Project

The human genome project began in the United States in 1990. The project was seen as being so large that it would take 15 years to complete. Recent advances in technology reduced the time to 10 years. This means we began looking at the first results of this research in 2001.

The Canadian government has established a fund of $5 million a year for the Medical Research Foundation to become a part of the project to understand the human chromosome. The human genome project had many parts to its task:

- identify all the approximately 100 000 genes in human DNA
- determine the sequences of the 3 billion chemical bases that make up human DNA
- store this information in databases
- develop faster, more efficient sequencing technologies
- develop tools for data analysis
- address the ethical, legal, and social issues (ELSI) that may arise from the project

To help achieve these goals, researchers also studied the genetic makeup of several non-human organisms. These included the common human gut bacterium Escherichia coli, the fruit fly, and the laboratory mouse.

A **genome** is all the DNA in an organism, including its genes. Genes carry information for making all the proteins required by all organisms. These proteins determine, among other things, how the organism looks, how well its body metabolizes food or fights infection, and sometimes even how it behaves.

DNA is made up of four similar chemicals (called bases and abbreviated A, T, C, and G) that are repeated millions or billions of times throughout a genome. The human genome, for example, has 3 billion pairs of bases.

The particular order of As, Ts, Cs, and Gs is extremely important. The order underlies all of life's diversity, even dictating whether an organism is human or another species such as yeast, rice, or fruit fly, all of which have their own genomes and are themselves the focus of genome projects. Because all organisms are related through similarities in DNA sequences, insights gained from non-human genomes often lead to new knowledge about human biology.

An initial draft of the human genome was prepared in 2000, with advances made until its completion in 2003. Future work will include determining the function of the estimated 30 000 human genes.

At the same time, new knowledge raises difficult questions and concerns about the responsibilities of researchers as new applications for genetic research are found. Above all, we should watch for issues around

- privacy
- overestimating the ability of genome research to deal with disease
- patenting
- modifying the genetic code of parents and forever affecting their offspring
- how genetic modification can affect our roots as humans

Cystic Fibrosis Research

The following website provides information about cystic fibrosis.

- Cystic Fibrosis Canada
  www.cysticfibrosis.ca

Cystic fibrosis (CF) is an incurable, inherited disorder, affecting mainly the lungs and the digestive system.

In the lungs, where the effects of the disease are most devastating, CF causes increasingly severe respiratory problems. In the digestive tract, CF often results in extreme difficulty in digesting adequate nutrients from food.

Cystic fibrosis is an inherited disease. The gene responsible is recessive, meaning a child must receive both genes from the parents before exhibiting any signs of the disease. It is estimated that one in every 2500 children in Canada has cystic fibrosis.

Children with cystic fibrosis have a chronic cough producing a thick mucous. They also have a large appetite with weight loss. Cystic fibrosis is detected by using a "sweat test" where excessive salt in sweat is a primary indicator of CF.

The following "Research Milestones" outlines major achievements made by Canadian researchers.

*Research Milestones**

Canadian CF Research Achievements Funded by Cystic Fibrosis Canada

- **1970s**—Scientists introduce revolutionary diets which are unrestricted in fats, and make changes in pancreatic enzyme therapy, to help children with cystic fibrosis grow and gain weight.
- **1985**—Researchers map the gene responsible for cystic fibrosis to chromosome 7, helping to close in on the precise location of the gene.
- **1988**—Surgeons perform the world's first successful double-lung transplant on a person with cystic fibrosis.
- **1989**—Researchers discover the gene responsible for cystic fibrosis.
- **1990**—Scientists reverse the CF defect under laboratory conditions by constructing a normal version of the gene responsible for cystic fibrosis and transferring it into CF-affected cells, demonstrating the potential for treating cystic fibrosis through gene therapy.
- **1990**—Researchers identify the precise cells in the body affected by cystic fibrosis and obtain the first direct evidence that the dysfunctional CFTR (cystic fibrosis transmembrane conductance regulator) protein is a chloride channel.
- **1992**—Researchers establish a new therapeutic approach to treat *Pseudomonas aeruginosa* bacterial infections by using alternating courses of different antibiotics.
- **1998**—Scientists replace the dysfunctional protein in cystic fibrosis, CFTR, with functional CFTR protein in a mouse model, enhancing the possibility of CF protein replacement therapy.
- **1998**—Researchers discover how to ensure the CF mouse model survives beyond weaning, through dietary changes, and prepare normal CFTR protein for possible therapeutic use.
- **2001**—Investigators complete Phase I clinical trials for dextran, a compound that seems to prevent bacteria from sticking to CF-affected lungs and promote mucus clearance; and test Prolastin®, a compound that reduces lung damage.

* Source: Cystic Fibrosis Canada. "Research Milestones." May 2011. www.cysticfibrosis.ca/en/research/ResearchMilestones.php (6 May 2011). Reproduced with permission.

continued

- **2005**—Researchers demonstrate that cationic peptides—naturally occurring antibiotics—have the potential to reduce infection and inflammation in CF patients.
- **2007**—In a mouse model, researchers develop and test an effective vaccine against the bacterium *Burkholderia cenocepacia*—a harmful, even deadly, bacteria in CF lungs.
- **2008**—Researchers identify two modifier genes that affect lung disease severity and the age of the first onset of *Pseudomonas aeruginosa* bacterial infection.
- **2008**—Investigators identify a new approach to treating "lung flare-ups" by targeting a bacterium that aggravates *Pseudomonas aeruginosa* infections, instead of targeting *Pseudomonas aeruginosa* directly.
- **2008**—Scientists screen tens of thousands of compounds and identify several that seem to restore (or compensate for) defective CFTR protein activity.
- **2009**—Researchers identify a modifier gene that may increase the likelihood of liver disease in people with cystic fibrosis.
- **2009**—Researchers discover a gene therapy technique that could double the number and improve the condition of donor lungs, dramatically enhancing health for cystic fibrosis patients who have had transplants.
- **2009**—Scientists discover that the mutated gene that causes cystic fibrosis is also responsible for muscle loss in CF patients, paving the way for novel therapies to improve the function of the diaphragm and other muscles in CF patients.

Notice that in 1989 a Canadian research team found the gene for CF. Since that time, gene therapy has shown promise in the laboratory.

This outline demonstrates several important factors. First, Canada has contributed greatly to the extended lifespan that has characterized cystic fibrosis sufferers over recent years. Secondly, the list of scientific accomplishments points out how gene therapy will be used in the future as the next step in eliminating many diseases.

Genetic Engineering

The following website provides information about genetic engineering.

- Ontario Agri-Food Technologies
  www.oaft.org/

Ontario's biotechnology program demonstrates Canada's focus on the food industry and its relationship to biological engineering. The Ontario government has contributed $20 million to biotechnical research; the federal government has contributed a further $20 million for the same purpose.

government has contributed a further $20 million for the same purpose. Governments see biotechnology and genetic engineering as the next wave of prosperity in the food industry.

Genetically modified (GM) food has created considerable apprehension in people. Governments and industry are faced with the task of dealing with popular resistance to these kinds of foods.

The following website provides an alternate point of view to the use of genetically modified foods.

- The Ram's Horn
  www.ramshorn.ca

The following website provides links to sources about food technology.

- Canadian Institute of Food Science and Technology
  www.cifst.ca/default.asp?ID=895

Genetic Counselling

The following website provides information about genetic counselling.

- Canadian Association of Genetic Counsellors
  www.cagc-accg.ca/

Genetic counselling involves providing medical information about genetic disorders in order to help people make personal decisions about their health, pregnancies, or their child's health care.

Genetic counselling is offered to people who are concerned about

- their own risks for having a genetic problem or for having a child with a problem because of their family history or their ethnic background
- a child with a genetic/medical condition
- pregnancy at 35 years of age or older
- prenatal testing such as amniocentesis, chorionic villi sampling, maternal serum screening, and ultrasound
- exposure to potentially harmful substances during pregnancy

Gene Therapy

Gene therapy involves manipulating genes in order to change genetic material in a plant, human, or other animal to fight or prevent disease.

One goal of gene therapy is to provide a patient with repaired or healthy copies of diseased genes. The patient undergoing gene therapy does not receive medicine as such, but receives a genetic modification to deal with the problem.

Gene therapy is still very new and experimental. This method of treating disease also takes us to new areas where we must explore and deal with social, moral, and legal considerations.

Summary

Our world has seen startling advances in our understanding of the human genetic code and the development of reproductive technologies. In vitro fertilization, embryo transfer, and artificial insemination allow couples unable to conceive naturally to have children. The ongoing development in the treatment of diseases such as cystic fibrosis suggests that if we can maximize our understanding of our genes—our basic building blocks—we can vastly improve our quality of life and the lives of those suffering with currently “incurable” diseases.

At the same time, it is important that we approach our new technologies and knowledge with responsibility and an understanding that manipulating the very foundations of life can have serious impacts upon our species and our world.

Notes

Lesson 16: Potential Applications and Implications of Biotechnology

Lesson Focus

After completing this lesson, you will be able to

☐ defend your position on a biotechnology-related issue

☐ write a newspaper article outlining current research and findings related to the topic

Key Words

- mutations
- genetic technology
- transgenic
- recombinant DNA
- cloning
- amniocentesis
- DNA fingerprinting

Online Resources

Two articles from Time Magazine (TIME, July 31, 2000) describe the current controversy about genetic engineering in food and beta-carotene enhanced rice.

- Margot Roosevelt. "Inside the Protests: Taking It to Main Street"
  www.time.com/time/magazine/article/0,9171,997621,00.html

- Simon Robinson. "Grains of Hope"
  www.time.com/time/magazine/article/0,9171,997586,00.html

The following websites provide information about biotechnology.

- National Agricultural Library
  www.nal.usda.gov

- Council for Biotechnology Information
  www.whybiotech.com

The following website provides information about DNA finger printing.

- National Health Museum
  www.accessexcellence.org/RC/AB/BA/DNA_Fingerprinting_Basics.php

The following website provides information about cloning and bioengineering.

- Oracle Education Foundation
  http://library.thinkquest.org/06aug/01611/

Introduction

In this chapter, you will be introduced to several controversial areas of biotechnology, including genetically modified foods, cloning, amniocentesis, and DNA fingerprinting. You will then perform your own investigative research into a biotechnology topic of your choosing.

Mutations

You have seen that mutations can occur in many different ways. A naturally occurring mutation can result from a mistake in the reproductive process (mitosis). Somatic or body cells can mutate approximately once every 3 billion cell reproductions. These mutations may or may not have an impact on the organism. The impact would normally be small and would not be passed on to the next generation.

A more common form of accidental mutation can occur when we come in contact with a mutagenic agent. Mutagenic agents consist of some forms of electromagnetic radiation such as X-rays, gamma rays from atomic reactions or atomic weapons testing, or ultraviolet light on the skin. You will have heard many warnings about going outside without skin covering in the summer. There is some concern about excessive use of cell phones and living near hydroelectric lines for the same reason. Chemical mutagenic agents include polychlorinated biphenyls or PCBs (chemicals used in oils, inks, and dyes), bisphenol A or BPA (found in hard plastics such as that in some water bottles), many organic compounds, and pesticides. Some foods seem as if they might also function as mutagenic agents. Mutagenic agents have the capacity to alter the DNA in our body and disrupt the reproductive process. As a result, cells are altered and are capable of producing other altered cells. The mutated cells can multiply continuously and become cancerous. Sometimes the mutagens can alter the sex cells of the individual, in which case there is a mutated offspring. The effects of radiation have been known for some time from the atomic bomb explosions in Hiroshima and Nagasaki, and the effects from Chernobyl are becoming known as well.

Genetic Technology

There has been a growing understanding of the structure of our genetic makeup. Researchers have completed determining the list of genes in our chromosomes. There are still some unknowns in the human genome and the hard work is continuing. The genomes of some insects and animals have already been mapped. Once the human genome has been fully mapped and understood, there will be the opportunity to manipulate the genetic makeup of any human. This is called genetic engineering.

We have already heard about genetic engineering in plants. These plants are sometimes called genetically modified (GM) foods. There is a great deal of concern about genetically modified foods. Sometimes concern is based on fear and lack of knowledge. Sometimes concern is based on whether we should allow scientists total approval on any kind of research and advancement regardless of the consequences. Since each of us is going to be affected by advancements in genetic science, we need to be aware of the issues in order to help develop positive and effective advancements in these areas.

Genetic engineering takes different forms. In one case, DNA from one organism can be taken to another, giving the second organism characteristics of the first. This method of genetic engineering produces a transgenic organism. A new type of rice called golden rice demonstrates this characteristic. Regular rice receives snippets of DNA from bacteria and daffodils producing beta-carotene in the rice, giving it the golden colour from which its nickname is derived. The scientist who developed the rice envisioned children in Third World countries being fed such rice to help their eyesight and fight against disease. He saw this as a first step in the production of many more grains of this type that could do wonderful things such as fight insects without sprays, fertilize itself, and overcome drought. There have been objections about using this rice, and similar GM foods, until they have been more thoroughly studied. Recall from Lesson 5 that plants perform meiosis by releasing pollen to be collected by another plant. Pollen and seeds from transgenic plants could very easily spread to surrounding land and take up root. A GM crop with harmful side-effects could become very difficult to control and contain. Other possible downsides to GM crops are the creation of new allergens, as well as strengthening the resistance of harmful species. By mixing together the properties of different foods, we could also create new allergy-inducing foods. Furthermore, growing crops with resistance to herbicides and insects could spur the growth of stronger weeds and insects that are resistant to traditional sprays and pesticides, creating an even larger problem for farmers.

A second type of genetic engineering called **recombinant DNA** has been around since the early 1970s. Bacteria exchange short strings of DNA called plasmids during conjugation. Scientists could change some plasmids and reintroduce them during conjugation. Cutting bacteria DNA at certain points along its length changes plasmids. A type of enzymes can do this task, allowing the bacteria DNA to be replaced with DNA fragments from a different source. A newly modified set of genetic material is easily introduced into the bacteria.

Plant and animal breeding is a time-consuming process. Minor modifications can take many years to develop. Genetic engineering allows dramatic changes to take place within a short time. Genetic engineering can also be used to eliminate diseases in humans.

Cloning

Cloning has captured the imagination of people. We have known about cloning for many years. A carrot was produced from a single cell in 1958. Placing the nucleus of a cell from one mouse in an unfertilized egg cell taken from another mouse produced clones of mammals. The mouse must have the developing embryo removed at an early stage (before developing beyond eight cells).

Most of us are aware of the “Dolly revolution.” British scientists were able to clone a sheep called Dolly. Suddenly, the cloning of humans was a possibility.

Amniocentesis

Amniocentesis allows an expectant mother to determine if her baby will have any genetic diseases. A slender needle is used to remove about one tablespoon of amniotic fluid surrounding the baby. A chromosome analysis is performed on the fluid. One of the primary detections is the presence of Down’s syndrome. Down’s syndrome appears more often in women 35 years or older; consequently, they are often encouraged to have the test performed. An alpha-fetoprotein test also determines whether the child will have spina bifida, a spinal defect. A mother having this test and finding a positive result will need to make a decision about her unborn child. As you can see, genetic technology has an impact on our lives.

DNA Fingerprinting

DNA fingerprinting has become a well-known procedure in our society. We have heard of cases where a person’s guilt or innocence is based on DNA fingerprinting evidence.

Every person has a unique fingerprint. Court cases have been settled using this technology for many decades now. The suspect leaves a fingerprint at the scene of the crime, and a police officer dusts the print, extracts it, and compares it to a list of prints of possible suspects. DNA fingerprinting doesn't really involve fingerprinting as we know it. If someone leaves behind a piece of hair or some blood or any cells from their body, they leave behind a unique set of chromosomes. Each one of us has a unique set of chromosomes and these chromosomes are the same regardless of where the cell came from in our body. Once these cells are located, the identity of the DNA is established and the criminal is caught—as long as we know the suspect's DNA.

There are some people who would like to register every baby's DNA so that crime prevention would become much easier. Do you think we should do this?

DNA fingerprinting can also be used to diagnose inherited diseases either before or after the child is born. Diseases such as cystic fibrosis, hemophilia, Huntington's disease, familial Alzheimer's, and sickle-cell anemia could be detected long before the disease shows itself. Prospective parents could be warned of the defective DNA before the child is born or they could know the probability of having a genetically affected child before conception.

DNA fingerprinting is performed on children all over the world. People performing DNA fingerprinting on their child may be forced to make a decision regarding their care based on finding a genetic mutation.

You can see that genetic technology brings many decisions and concerns with it. Decisions will have to be made at a government/social level and at a personal level before we can learn to live comfortably with this new technology.

Summary

As we uncover more information about the genetic code and diseases such as cystic fibrosis that are related to our genes, genetic mutations are becoming a growing concern for our society. At the same time, new and fascinating technologies have appeared with the potential to alter our world for the better. On the other hand, is there a limit to how far we should develop these technologies?

Is there a need to produce genetically identical organisms? Do we have the right to decide whether an unborn child lives? Are we applying a "guilty until proven innocent" mentality by registering every individual's DNA? These are important questions that need to be addressed.

Assignment 1.4: Research into Genetics (14 marks)

Online Resources

The following website provides information about Canadian contributions to health research, including contributions to the fields of genetics and reproductive technology.

- Canadian Institutes of Health Research
  www.cihr-irsc.gc.ca/e/35216.html

Canadians have contributed over the years to the field of genetics and reproductive technology. Some contributions that you may want to research include the following (Canadian Institutes of Health Research).

1920s Insulin changes lives of diabetics
Drs. Banting, Best, Collip, and Macleod discovered insulin, revolutionizing the treatment of diabetes.

1930s Treating seizures in Montreal
Dr. Wilder Penfield developed a surgical method for treating epilepsy.

1940s Jumpstarting molecular research
Dr. Maud Menten performed the first protein separation using electrophoresis, which is the standard research tool in genetics and other biological sciences.

1950s Healing Hodgkin's disease
Dr. Vera Peters uses radiation to treat Hodgkin's disease. Once thought to be incurable, Hodgkin's now has a survival rate of more than 90 percent.

1960s Stem cells discovered
Drs. James E. Till and Ernest A. McCulloch discover the hemopoietic stem cell, which is the basis for bone marrow transplantation.

1960s Discovery saves babies' lives
Dr. Bruce Chown eliminates Rh disease, which had claimed the lives of many babies whose blood was incompatible with their mothers' blood.

continued

1970s Trying on some new genes
Dr. Frank Graham co-develops a simple method of inserting extra copies of genes into animal cells. His research represents a big step forward in the development of cancer gene therapy.

1970s Fighting infertility
Dr. Henry Friesen discovered the hormone called prolactin, high levels of which can cause infertility in humans.

1980s Cystic fibrosis gene found
Drs. Lap-Chee Tsui, Manuel Buchwald, and Jack Riordan discover the gene that causes cystic fibrosis.

1990s More Alzeimer's genes
Dr. Peter St George-Hyslop discovers and clones two genes, called presenilins, responsible for early-onset Alzheimer's disease.

2000s Early screening for a deadly disease
Dr. Jacques Drouin identifies a gene responsible for severe hypoglycemia in infants. His discovery leads to better screening for the disease and saved lives.

1. Do some research into Canadian contributions in the field of genetics and reproductive technology. Find one article (from a newspaper, magazine, or website) to analyze.
2. In your own words, write a brief summary of the article, describing the author's main point(s).
3. Determine whether the article is a fact-based article (that is, one that presents only facts without expressing a point of view on the subject) or an issue-based article (one that presents a particular opinion or point of view on the subject).

   — For a fact-based article, explain any questions you have about the topic, and whether you would support the research in the article or not. Be sure to explain your reasoning.

   — For an issue-based article, state whether you agree or disagree with the author's opinion, making sure to explain your position.

Your analysis should be approximately 250 words long (one page of double-spaced text, with the pictures or other graphics not included in the page total), and you should include a copy of the article for your tutor/marker. To help organize your thoughts, you may wish to complete the appropriate article analysis chart on pages 147 to 148.

Your analysis will be assessed using the following rubric:

Content	Length and Style	Sources Used	Grammar, Neatness, and Spelling	Total Marks
8 marks	2 marks	2 marks	2 marks	14 marks
■ summarizes the contributions to the field of genetics/reproduction described in the article, drawing connections to information from Module 1 *(3 marks)* ■ clearly states support for/against the research or author's opinion, providing a detailed rationale for the position *(5 marks)*	At least one typewritten page, double-spaced, using a font no larger than 12. May contain pictures (but these do not count towards length requirements).	Analysis includes a copy of the article that lists the author, title, original source, and date of publication.	Half-mark removed for each error.	
/8	**/2**	**/2**	**/2**	**/14**

Notes

Analyzing a Fact-Based Article

Title of article:
Source of article:
Date of article:

Main Idea:

Summarize the main points in your own words.

Draw a diagram to represent the main points.

In point form, list the facts presented, underlining <u>five key words</u>.

Write two questions you have about the topic.

What further information do you feel you need on this issue?

Explain why the ideas in this article are important or not important:

Reference: Matchullis, Lynda, and Better Mueller. “Strategies for Success: Effective Teaching for the Whole Class.” Unpublished source material, 1994.

Analyzing a Issue-Based Article

Title of article:
Source of article:
Date of article:

What question does this article address?

State the author's opinion in your own words.

State in point form the evidence given to back up this opinion.

Draw a diagram to represent the author's perspective on the issue.

Do you agree or disagree with the author? Explain.

What further information do you feel you need on this issue?

Explain why the ideas in this article are important or not important:

Reference: Matchullis, Lynda, and Better Mueller. "Strategies for Success: Effective Teaching for the Whole Class." Unpublished source material, 1994.

LESSON 17: REPRODUCTION REVIEW

Lesson Focus

This lesson contains a review learning activity that you can use to test your knowledge of the concepts within this module.

Learning Activity 1.16: Reproduction Review

Multiple Choice

Circle the choice that best matches the question.

1. Which of the following is not part of the cell nucleus?
   a. nuclear membrane
   b. cell wall
   c. chromosomes
   d. nucleolus
2. Plant and animal cells differ in that
   a. plants have chromosomes and animals do not
   b. animals undergo mitosis and plants do not
   c. plants have a cell wall and animals do not
   d. animals have a cell nucleus and plants do not
3. Reproduction is necessary for life to continue. Which of the following types of reproduction would require meiosis?
   a. healing and tissue repair
   b. growth
   c. sexual reproduction of the organism
   d. all of the above

4. Sperm and egg cells combine to form a
    a. zygote
    b. gonad
    c. haploid cell
    d. homologous pair
5. A somatic cell is a
    a. sex cell
    b. diploid cell
    c. body cell
    d. daughter cell
6. Bacteria reproduce sexually by conjugation. In conjugation, the bacteria exchange genetic information using packets of genetic material called
    a. plasmids
    b. bridges
    c. chromatins
    d. cytoplasm
7. The interphase is a part of
    a. mitosis
    b. cell division
    c. the cell cycle
    d. cytokinesis
8. Yeast reproduce by
    a. sporulation
    b. mitosis
    c. sexual reproduction
    d. budding

9. The ovary contains corpus luteum during the later part of ovulation. Its function is
    a. to provide hormones if pregnancy begins
    b. to push the egg cell out of the ovary
    c. to move the egg cell into the uterus
    d. to remove the egg cell if fertilization did not take place
10. The female hormone responsible for preparing the uterus for the egg cell is called
    a. androgen
    b. testosterone
    c. estrogen
    d. progesterone
11. Which of the following is/are true of sperm?
    a. produced in seminiferous tubules
    b. has a tail for moving
    c. located in semen
    d. all of the above
12. During the first eight weeks of pregnancy, the developing child is called
    a. a zygote
    b. an embryo
    c. a fetus
    d. a newborn
13. The sex of a child is determined
    a. at fertilization
    b. by the father
    c. by XY chromosomes
    d. all of the above

14. A single trait in an offspring

    a. can only come from a dominant gene

    b. must be present in both genes from the parents

    c. cannot come from recessive genes from both parents

    d. can only come from the male gamete

15. Sex-linked traits

    a. are located on the Y chromosome

    b. can be passed from father to son

    c. can be passed from mother to son

    d. are no different from ordinary traits

16. A mother with a homozygous recessive trait for straight hair (“c” since curly hair is dominant) would

    a. be labelled “cc” for the mother genotype

    b. produce 25 percent curly-haired offspring with a heterozygous curly-haired father

    c. yield only heterozygous offspring

    d. all of the above

17. An allele

    a. is another name for a chromosome

    b. determines the sex of the offspring

    c. is a variation of a gene relating to the same characteristic

    d. is responsible for determining sex-linked traits

Use the Punnett square below to answer the next two questions.

Father

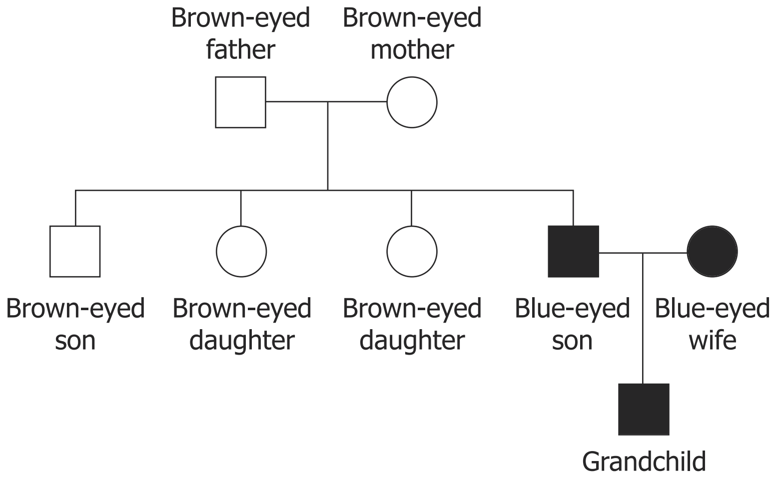
		D	d
Mother	d	Dd	dd
	d	Dd	dd

A father has a dominant gene "D" for dark hair and a recessive gene "d" for light hair.

A mother has two recessive genes for light hair.

18. The father is
    a. homozygous light hair
    b. heterozygous dark hair
    c. heterozygous light hair
    d. homozygous dark hair
19. The offspring will be
    a. 100 percent heterozygous dark hair
    b. 50 percent heterozygous dark hair
    c. 25 percent homozygous light hair
    d. 75 percent heterozygous dark hair

20. Using the pedigree below and knowing blue eyes come from a recessive gene, choose the true statements.



a. There is a 25 percent chance of a blue-eyed grandchild.

b. There is a 50 percent chance of a blue-eyed grandchild.

c. There is a 75 percent chance of a blue-eyed grandchild.

d. There is a 100 percent chance of a blue-eyed grandchild.

Questions

1. Match the terms in the left column with the descriptions in the right column.

_____ cell membrane

_____ nucleus

_____ cytoplasm

_____ Golgi complex

_____ chromosome

a. packages and stores proteins

b. contains all the information needed for cell reproduction

c. controls transport of materials in and out of the cell

d. command centre of the cell

e. filled with organelles that perform the cell functions

2. State the three parts to the cell theory.

a. ____

b. ____

c. ____

3. Cell division is a common method for reproduction in living things. Describe what happens in cell division, using the following words: *cell cycle*, *mitosis*, *cytokinesis*, and *interphase*.

4. State the name given to the type of asexual reproduction for the following:

   a. bacteria ____

   b. moulds ____

   c. yeast ____

   d. starfish ____

   e. plants ____

5. Each body cell in a certain organism has 28 pairs of chromosomes.

   a. What is the diploid number of chromosomes for this organism? ______

   b. What is the haploid number of chromosomes for this organism? ______

   c. How many chromosomes would a male sperm have? ______

   d. How many chromosomes would a female egg have? ______

   e. How many chromosomes would there be after the sperm and egg unite to form a zygote? ______

6. Fill in the blanks with the appropriate term from this list: *1n*, *2n*, *meiosis*, *mitosis*.

   When sexual reproduction takes place,

   a. the male sperm reproduce through a process called _________________

   b. in a human, the female egg would contain __________ chromosomes

   c. once the egg and sperm unite to form a zygote, the remaining cell reproduction is through _________________

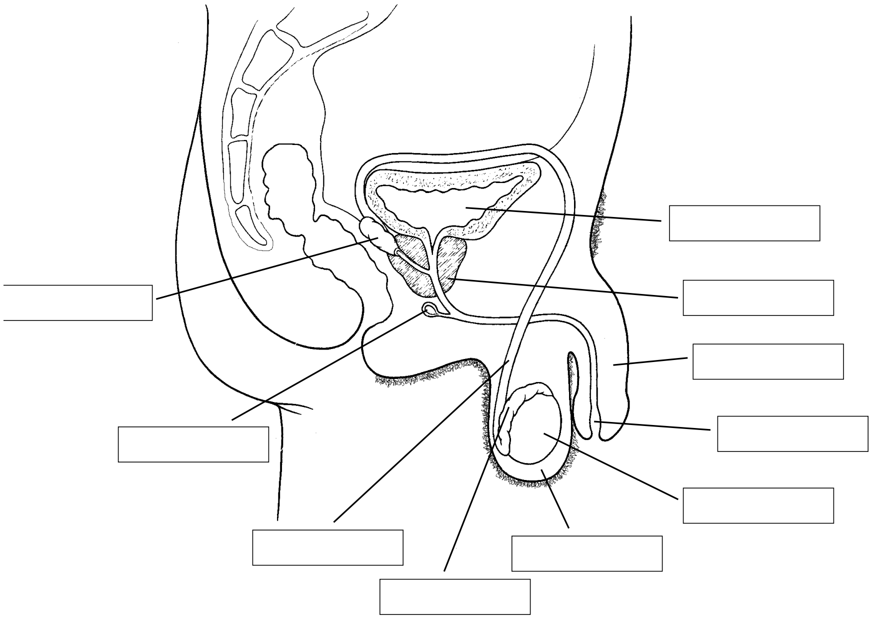
7. Match the term in the left column with the description in the right column.

_____ sperm	a. part of female sex organ in plants
_____ stigma	b. sex organ in females and males
_____ egg	c. male sex cell
_____ pollen	d. male sex cell in plants
_____ gonad	e. female sex cell

8. Complete the contrast table shown below.

	Asexual Reproduction	**Sexual Reproduction**
Number of parents		
How offspring compare to parents		
Ability to respond to new environment		

9. Fill in the blanks to label the diagram below.



10. Match the terms in the left column with the descriptions in the right column.

____ scrotum

____ vas deferens

____ testes

____ endometrium

____ epididymis

____ semen

____ fertilization

____ testosterone

____ hypothalamus

____ estrogen

____ ovulation

____ ovary

a. controls the release of sex hormones

b. male sex hormone

c. keeps sperm at constant temperature

d. female sex hormone

e. male sex organ that produces sperm

f. a fluid that accompanies sperm and helps it travel

g. female gonad

h. a duct that carries sperm to the urethra

i. a place where sperm mature and are stored

j. occurs when a sperm comes in contact with an egg

k. the process of providing a mature egg cell for fertilization

l. provides nourishment for the developing embryo

11. Name three indicators of puberty in a male.

a. ____

b. ____

c. ____

12. Describe the formation of an egg cell and its movement to prepare for fertilization. Use the following terms: *uterus*, *ovary*, *oviduct* (*fallopian tube*), *endometrium*.

13. What takes place during
    a. ovulation?
    b. menstruation?

14. Place the following terms in order from smallest to largest: *chromosome*, *DNA*, *gene*.

    smallest ____

    middle ____

    largest ____

15. The gene for yellow colour (Y) in peas is dominant and the gene for green colour (y) is recessive. Plant A that has one yellow dominant gene and one green recessive gene is crossed with Plant B that has two green recessive genes.
    a. Show the colour genotype for each plant.
    b. What is the phenotype for each plant?
    c. Complete the Punnett square for the offspring of the cross between the two plants.

Plant A

		Y	y
Plant B	y		
	y		

    d. What percentage of the time will the offspring be
        i. green? __________
        ii. yellow? __________
    e. List any homozygous offspring.

16. The sex-determining chromosomes are the X and Y chromosomes.
    a. What is the X,Y chromosome pair for
        i. a male? __________
        ii. a female? __________
    b. Draw a Punnett square showing the possible sex of the offspring for a mother and father.
    c. According to your Punnett square, what percentage will be male and female offspring?
        i. Male __________
        ii. Female __________
    d. A mother has a recessive gene for colour-blindness on the X chromosome. Will she pass the recessive gene to her
        i. daughter? __________
        ii. son? __________
17. Teddy the bear has a strong desire to eat gumdrops. Whenever he can get them, he will overdose. Teddy also loves to sunbathe. The gumdrops have created a mutation in his body cells that result in an oversized left ear. His sunbathing has resulted in a mutation in his sex cells which have a tendency to cause superior guitar playing.
    a. Could any of his offspring have oversized left ears? ______
    b. Could any of his offspring be superior guitar players? ______
    c. Explain your answers to (a) and (b).
18. Name two environmental factors responsible for genetic mutations.
    a. ____
    b. ____
19. What is a chromosomal mutation?
20. Name one way that Canada has developed genetic technology.

Check the answer key.

Notes

MODULE 1 SUMMARY

Congratulations! You have finished the first module of Grade 9 Science.

Submitting Your Assignments

It is now time for you to submit Assignments 1.1 to 1.4 to the Distance Learning Unit so that you can receive some feedback on how you are doing in this course. Remember that you must submit all the assignments in this course before you can receive your credit.

Make sure you have completed all parts of your Module 1 assignments and organize your material in the following order:

- Module 1 Cover Sheet (found at the end of the course Introduction)
- Assignment 1.1: Dual Option Assignment
- Assignment 1.2: From Conception to Birth
- Assignment 1.3: Mutagens Investigation
- Assignment 1.4: Research into Genetics

For instructions on submitting your assignments, refer to How to Submit Assignments in the course Introduction.

When you complete all four modules of this course, you will write your final examination. Instructions for arranging to write your final examination and information regarding the final practice examination can be found in the Introduction and at the end of Module 4.

Notes

MODULE 1

Learning Activity Answer Key

MODULE 1
LEARNING ACTIVITY ANSWER KEY

LESSON 1

Learning Activity 1.1

1. Describe the path of a protein molecule from the place where they are produced to the place where they are used in the cytoplasm.

   Protein is manufactured in the ER (endoplasmic reticulum). After it is produced, it moves throughout the ER. The protein passes to the Golgi complex. In the Golgi complex, protein is packaged and stored in the cytoplasm for later use.

2. If the endoplasmic reticulum is the transportation system, then the Golgi complex is the warehousing and packaging system. Explain this statement.

   The protein moves through the many folds of the ER and is packaged in the Golgi complex.

3. What part of the nucleus replicates itself as part of the reproductive process?

   The chromosomes replicate themselves.

4. Why is the packaging of proteins in the Golgi complex an important part of the cell's function?

   The Golgi complex stores proteins until they are needed. For example, enzymes are proteins which control chemical reactions in cells. Hormones are also proteins. These chemicals control many processes in the body.

LESSON 2

Learning Activity 1.2: Stages of Mitosis

1. What happens to the nucleus of a cell before mitosis begins?

   Chromosomes must duplicate themselves before cell division can begin.

2. What is the purpose of mitosis?

   The purpose of mitosis is to produce another cell that is identical to the original cell.

3. Why is cytokinesis a necessary part of cell division?

   Cytokinesis is the process of sharing cytoplasm between two developing cells.

4. What happens to the cell during interphase, the time in between cell division?

   The cell grows and matures during interphase.

LESSON 3

Learning Activity 1.3: Asexual Reproduction

1. How does the daughter cell compare to the parent?

   The daughter cell is identical to the parent.

2. Describe one method of vegetative propagation.

   Strawberries reproduce through the use of runners; see page 26 for more detail.

3. Name two ways that fungi reproduce.

   Budding and spore formation are two ways that fungi reproduce.

4. What name is given to the reproduction of bacteria?

   Binary fission is the name given to the reproduction of bacteria.

5. Compare and contrast the ways that humans and bacteria use mitosis.

   Humans and bacteria are both capable of mitosis. Humans use mitosis to regenerate or repair tissues. Bacteria use mitosis to create identical copies of themselves (offspring).

6. List the type of asexual reproduction occurring in each scenario. Some types may appear more than once.
   a. a starfish regrowing a lost limb **regeneration**
   b. bread dough rising in a pan **budding**
   c. grass regrowing after it has been mowed **regeneration**
   d. staying home sick because of a bacterial infection **binary fission**
   e. mushrooms growing on a lawn **spore formation**
   f. roots developing out of a broken-off apple tree branch **vegetative propagation**
   g. mold spreading over a loaf of bread **spore formation**
7. State three advantages of asexual reproduction.

   See Summary, page 27.

LESSON 4

Learning Activity 1.4: Meiosis

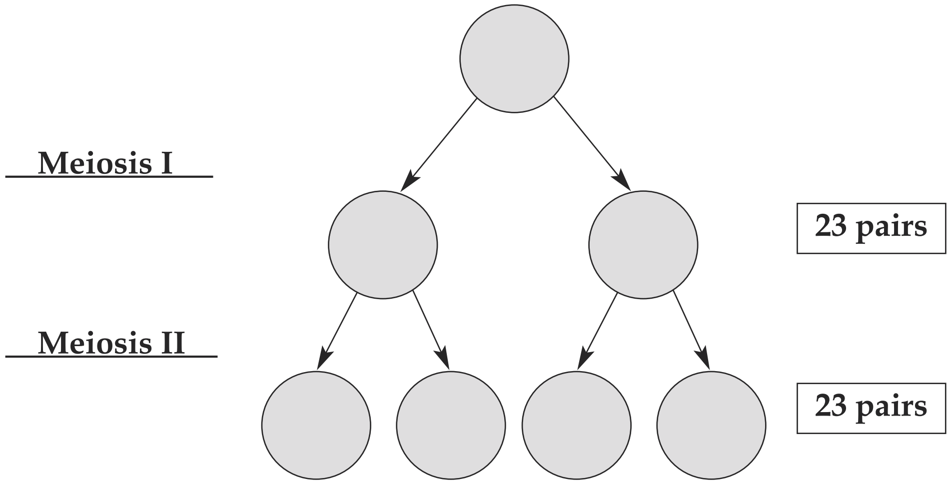
1. State two differences between a somatic cell and a reproductive cell.

   Somatic cell = 2n; reproduction cell = n

   A somatic cell is identical to the parent; a reproduction cell is different from the parent.
2. State two ways in which asexual and sexual reproduction differ.

   Asexual reproduction always produces offspring identical to parent, whereas sexual reproduction produces offspring different from the parents. Asexual reproduction requires only one parent, whereas sexual reproduction requires two parents.

3.



4. What would happen to the offspring in sexual reproduction if meiosis did not occur?

   If meiosis did not occur, the offspring would have too many chromosomes.

5. An animal has 54 chromosomes in a somatic cell.
   a. What is the diploid number for this animal? **54**
   b. What is the haploid number for this animal? **27**
   c. How many chromosomes does a gamete have? **27**
   d. How many chromosomes does an egg have? **27**
   e. When the egg and sperm combine, how many chromosome are there? **54**
   f. How many chromosomes does a cell taken from the animal's muscle have? **54**

6. Fill in the blanks for the following statements.
   a. A male gamete is called a(n) **sperm** and a female gamete is called a(n) **egg**.
   b. When two gametes unite, they form a(n) **zygote**.
   c. The two stages of meiosis are **Meiosis I or reduction** and **Meiosis II or division**.
   d. During **meiosis** reduction takes place.
   e. One parent cell will produce **four** daughter cells in meiosis.

7. What are the two characteristics that identify mitosis?
   a. **There is one parent.**
   b. **The offspring are identical.**

8. Complete the crossword puzzle below.

   Across

   3. the name given to a fertilized egg cell
   4. parts of a chromosome
   5. male gamete

   Down

   1. the name given to a body cell
   2. sexual reproduction
   4. the name given to a reproductive cell
   6. female gamete

			^{1}S		^{2}M								
^{3}Z	Y	G	O	T	E								
			M		I				^{4}G	E	N	E	S
			A		O				A				
			T		^{5}S	P	^{6}E	R	M				
			I		I		G		E				
			C		S		G		T				
									E				

LESSON 5

Learning Activity 1.5: Animal and Plant Reproduction

1. Name the male and female sex cells in animals.

   Sperm, Egg

2. Where are the male and female sex cells produced in animals?

   Testes, Ovaries

3. Name the male and female sex cells in a plant.

   Pollen, Eggs

4. Describe the process of sexual reproduction in a plant from pollen touching the stigma to fertilization.

   Pollen touch the pistil and stick to it. The pollen produces a pollen tube that travels through the pistil to the receptacle. The nucleus of the pollen travels to the egg which it fertilizes.

5. What type of cell reproduction takes place after the egg cell is fertilized?

   After the egg is fertilized, the zygote reproduces by mitosis.

6. An animal has 64 chromosomes.
   a. What is the haploid number for this animal? **32**
   b. What is the diploid number for this animal? **64**
   c. How many chromosomes will its sperm have? **32**
   d. How many chromosomes will be found in its liver cells? **64**

7. Describe the cells produced during Meiosis I. How are they different from the cells produced by Meiosis II?

   The cells produced during Meiosis I have a haploid number of double-stranded chromosomes. The cells produced by Meiosis II are also haploid, but they contain only single-stranded chromosomes.

LESSON 6

Learning Activity 1.6: Reproductive Success

1. Name two advantages of asexual and sexual reproduction.

   Asexual

   a. Every organism is capable of reproducing, not like sexual reproduction where half of the population has that ability.

   b. Since every offspring is identical, a favourable environment will allow extremely fast population growth.

   Sexual

   a. Genetic variation allows excellent response to changes in environment.

   b. Plants and animals that are not able to move can assume both male and female characteristics.

2. Name five ways that sexual reproduction is enhanced by adaptation. *(Any five of the six answers are correct.)*
    a. **behaviour**
    b. **appearance**
    c. **mating calls**
    d. **chemical cues**
    e. **courting behaviour**
    f. **number of offspring**
3. Appearance is an important element of reproductive success. For the following scenarios, decide which organism would stand a better chance of reproducing, and explain your choice.
    a. an Arctic hare with a pure white coat or an Arctic hare with a spotty, brown coat

       White coat. An Arctic hare with a brown coat would stand out against the white snow and have difficulty avoiding predators.
    b. a large caribou with a large rack of antlers or a gangly caribou with one antler broken off

       Large caribou. The thin caribou would be weaker, and, lacking one antler, it would be at a disadvantage when competing for females.
    c. a flower with bright red petals or a flower with spotted black petals

       Bright red. Brilliant colours attract pollinators such as birds and bees, increasing the likelihood that its male gametes would be distributed to other flowers.

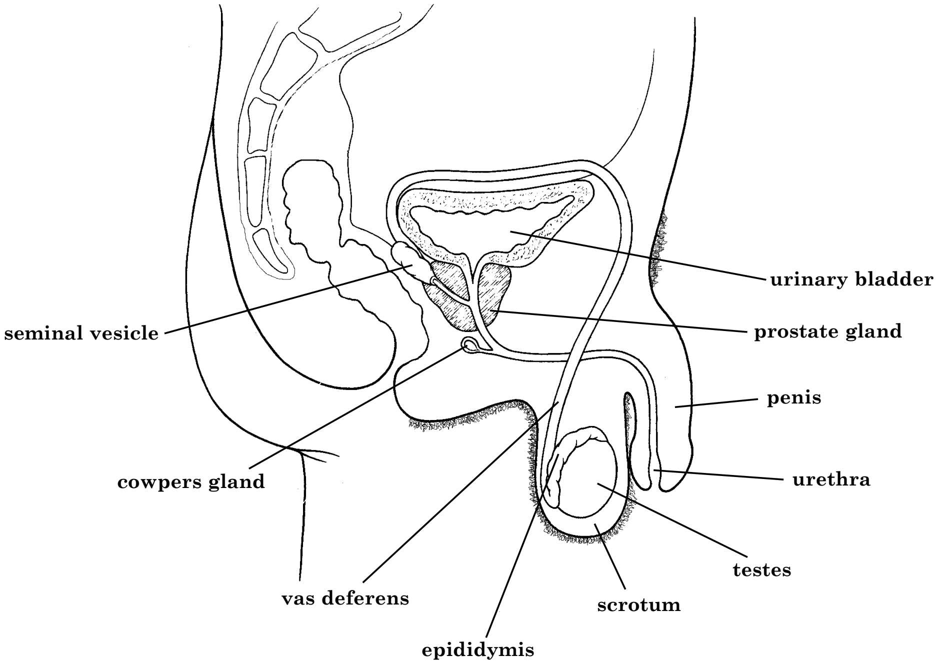
LESSON 7

Learning Activity 1.7: The Male Reproductive System

1. What are the main functions of the male reproductive system?

   The main functions of the male reproductive system are to produce sperm and to store the sperm.

2. Label the parts shown on the diagram below.



3. What part of the brain is responsible for the production of hormones?

   The hypothalamus is responsible for the production of hormones.

4. What two hormones are produced in the pituitary gland?

   The pituitary gland produces LH and FSH.

5. Where is the hormone testosterone produced?

   Testosterone is produced in the testes.

6. What functions does testosterone have?

   Testosterone is responsible for producing the following male characteristics:

   - **onset of sperm production**
   - **sexual organs grow and develop**
   - **voice changes; muscle and bone grow**

7. Write a brief description of the function of the sex organ or hormone in the table below.

Sex Organ/ hormones	Function
urethra	**tube in which semen or urine can travel**
epididymis	**place where sperm mature and are stored**
testes	**male sex organ where sperm are produced**
vas deferens	**carries sperm from epididymis to urethra**
prostate gland	**secretes a milky alkaline fluid into vas deferens**
seminal vesicle	**add fructose to sperm**
scrotum	**a pouch close to body that keeps sperm at constant temperature**
androgens	**male sex hormones as a group**
LH	**stimulates cells in seminiferous tubules to produce testosterone**
FSH	**combines with testosterone to stimulate sperm production**

LESSON 8

Learning Activity 1.8: The Female Reproductive System

1. What is the main sex organ in females?

   The main sex organ in a female is the ovary.

2. State the two phases of the female reproductive cycle and indicate where they occur.

   Ovulation, where the ovary prepares the egg for fertilization. (Ovulation takes place in the ovary.)

   Menstruation, where the uterus is prepared to nurture the fertilized egg as it develops into a mature embryo ready for birth. (Menstruation takes place in the uterus.)

3. How do the production of sex cells in males and females differ?

   Sex cells are produced in the male every day after puberty.

   Sex cells are produced in the female during her 14th to 20th week of development. A female is born with all her sex cells already inside her. The cells will mature at puberty when she will began her menstrual cycle.

4. What two hormones are present in both males and females?

   Both males and females produce LH and FSH but they have a different effect in each sex.

5. What hormone is characteristic of male reproduction and which one is characteristic of the female reproduction cycle?

   The main male reproductive hormone is testosterone and the main female reproductive hormone is estrogen.

6. Give a brief description of ovulation.

   During ovulation, the egg cell is released from the ovary into the oviduct. The oocytes and follicles develop to produce a secondary oocyte that breaks through the ovary wall to deposit a mature egg cell into the oviduct.

   The feathery ends of the oviduct, as well as contractions of the oviduct wall, push the egg into position to be fertilized. The sperm must encounter the egg during the one to two days for fertilization to take place.

7. What type of cell reproduction takes place in the zygote once fertilization occurs?

   Once fertilization takes place, cells reproduce by mitosis.

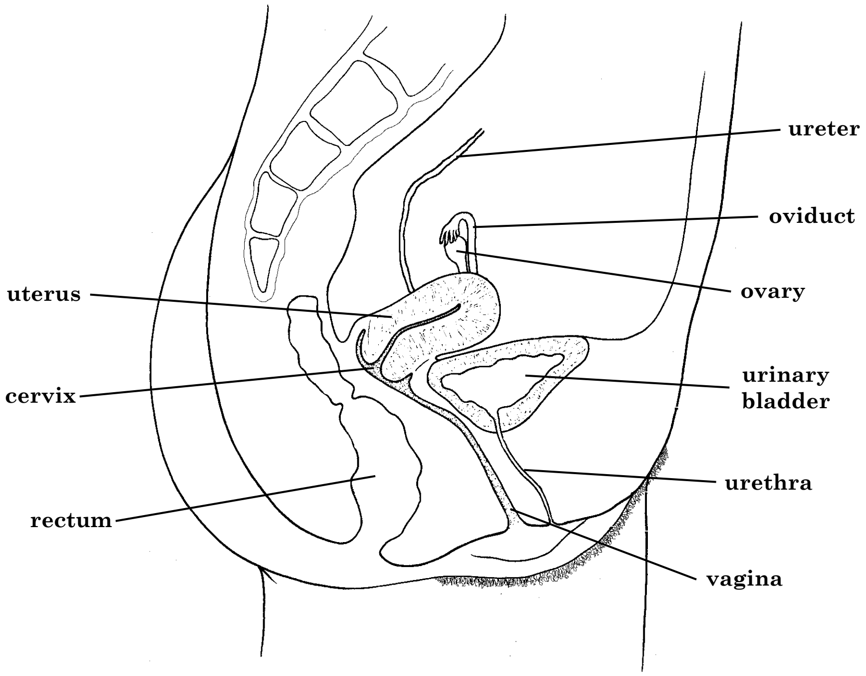
8. How many chromosomes are in each cell of the embryo?

   Each cell in an embryo contains 23 pairs of chromosomes (46 chromosomes).

9. Contrast the reproductive function of the human male and female.

   The male is responsible for the production and storage of sperm. The female is responsible for producing a mature egg cell that can be fertilized by a sperm from the male. The female is then responsible for the safekeeping of the child until birth.

10. Fill in the labels for the diagram showing the female reproductive system below.



LESSON 10

Learning Activity 1.9: Observing Traits

Data for Tables 1 and 2 will vary according to the people surveyed.

Does your family have a trait that is not as common in the general population? If so, what would be the reason for it?

An uncommon trait in your family could be the result of inheriting a recessive phenotype. Since recessive phenotypes appear only if *both* parents passed on the recessive trait to their offspring, they are less likely to appear in the general population.

Learning Activity 1.10: Tallness Trait

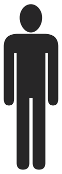
1. How many tall and how many short offspring will there be from these parents?

   Tall **4 (all)** (100%)   Short **0 (none)** (0%)

   You can predict the offspring that come from parents having heterozygous genes.

2. Both parents in the example below are heterozygous tall. Place the gamete symbols in their correct form for the two parents.

Tt



Tt

3. Place the gametes for the mother on top and for the father on the side of the Punnett square. Fill in the Punnett square.

	T	t
T	TT	Tt
t	Tt	tt

4. If the parents had 4 offspring, how many would you expect to be tall? short?

   Tall **3** (75%)   Short **1** (25%)

LESSON 11

Learning Activity 1.11: Attached/Free Earlobe Trait

1. Complete the Punnett square for the parents described on the previous page.

Mother

Father

	f	f
F	**Ff**	**Ff**
f	**ff**	**ff**

2. Describe the probable phenotypes and genotypes that come from the Punnett square. Indicate the percentage probability of each.
   a. Phenotypes: **50 percent free earlobe; 50 percent attached earlobe**
   b. Genotypes: **50 percent heterozygous free; 50 percent homozygous attached**

Learning Activity 1.12 Genotype and Phenotype

In the following examples dealing with the hair-type gene, G represents the dominant gene and produces curly hair, while g represents the recessive gene and produces straight hair.

Part A

An egg cell G and a sperm cell G unite:

1. The genotype of the resulting zygote will be
   ☒ GG ☐ gg ☐ Gg
2. The zygote will be
   ☐ heterozygous ☒ homozygous
3. The resulting human will have the following phenotype:
   ☒ curly hair ☐ straight hair ☐ part curly, part straight

4. The resulting human will be able to produce the following gametes:
   ☒ G ☐ g ☐ G or g

An egg cell g and a sperm cell g unite:

5. The genotype of the resulting zygote will be
   ☐ GG ☒ gg ☐ Gg
6. The zygote will be
   ☐ heterozygous ☒ homozygous
7. The resulting human will have the following phenotype:
   ☐ curly hair ☒ straight hair ☐ part curly, part straight
8. The resulting human will be able to produce the following gametes:
   ☐ G ☒ g ☐ G or g

An egg cell G and a sperm cell g unite:

9. The genotype of the resulting zygote will be
   ☐ GG ☐ gg ☒ Gg
10. The zygote will be
    ☒ heterozygous ☐ homozygous
11. The resulting human will have the following phenotype:
    ☒ curly hair ☐ straight hair ☐ part curly, part straight
12. The resulting human will be able to produce the following gametes:
    ☐ G ☐ g ☒ G or g

An egg cell g and a sperm cell G unite:

13. The genotype of the resulting zygote will be
    ☐ GG ☐ gg ☒ Gg
14. The zygote will be
    ☒ heterozygous ☐ homozygous
15. The resulting human will have the following phenotype:
    ☒ curly hair ☐ straight hair ☐ part curly, part straight
16. The resulting human will be able to produce the following gametes:
    ☐ G ☐ g ☒ G or g

Part B

State your answer to the following questions in the form of a fraction or a percentage.

17. If a father (GG) and a mother (gg) have children, what will be the expected proportion of the following genotypes?

    GG ______ gg ______ Gg **100%**

18. If a father (gg) and a mother (GG) have children, what will be the expected proportion of the following genotypes?

    GG ______ gg ______ Gg **100%**

19. If a father (Gg) and a mother (GG) have children, what will be the expected proportion of the following genotypes?

    GG **50%** gg **0%** Gg **50%**

20. If a father (Gg) and a mother (Gg) have children, what will be the expected proportion of the following genotypes?

    GG **25%** gg **25%** Gg **50%**

LESSON 12

Learning Activity 1.13: Punnett Squares and Pedigrees

1. There is a sex-linked condition called Mendelism that drives its victims to an unreasonable desire to construct Punnett squares. There is a sex-linked allele where normal (M) is dominant and Mendelism (m) is recessive. The mother X^MX^m and father X^MY have the shown sex-linked alleles. Use the information to answer the following questions.
   a. Describe the phenotype and genotype of the mother and father.

      Both the mother and father are normal. The mother is heterogeneous normal (X^MX^m).

   b. Use a Punnett square to show the probable offspring.

Mother

Father

	X^M	Y
XM	X^MX^M	X^MY
XM	X^MX^m	X^mY

c. State the phenotype and genotype of each possible offspring.

   i. **Female offspring with no Mendelism. Homogeneous normal.**

   ii. **Female offspring with no Mendelism. Heterogeneous normal.**

   iii. **Male offspring with Mendelism.**

   iv. **Male offspring with no Mendelism.**

d. Is there a possibility that any female offspring could be a carrier?

   There is a possibility of a female carrier as shown above. (2)

e. Is there any possibility of a male compulsive Punnett square constructor?

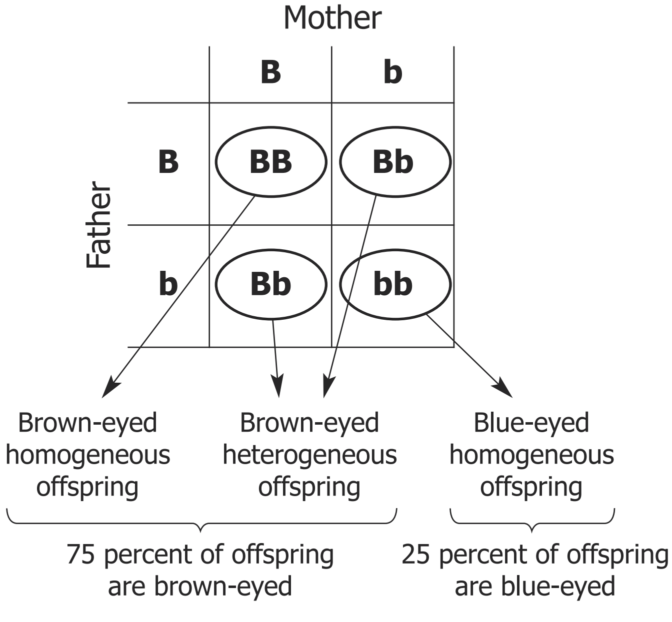
   One male is a compulsive Punnett square constructor. (3)

2. Use the eye colour pedigree example in the lesson to answer the following questions.

   a. State the genotype for

      i. mother and father

      Brown-eyed heterogeneous mother and father. We can state this by looking at their offspring. Twenty-five percent of the offspring are blue-eyed, which comes from a recessive gene. The 25 percent result can only come when both parents have the recessive gene.



      ii. children

      One child is blue-eyed homogeneous. Blue-eyed people must always be homogeneous since blue is recessive. We predict one offspring will be brown-eyed homogeneous and the other two will be brown-eyed heterogeneous.

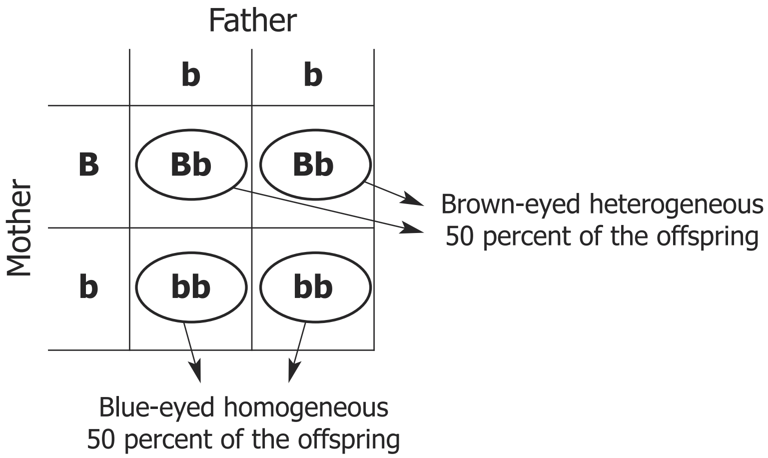
      iii. grandchild

      Blue-eyed child must be blue-eyed homogeneous.

b. What are the phenotypes for the children?

The children are 75 percent brown-eyed and 25 percent blue-eyed.

c. Draw a Punnett square for the possible offspring of a heterogeneous brown-eyed female in the second generation and a blue-eyed male.



LESSON 13

Learning Activity 1.14: Is it sex-linked?

1. If a recessive trait is sex-linked, how many genes must a male have to inherit it? a female?

   A male needs one gene; a female needs two.

2. If a recessive trait is not sex-linked, how many genes must a male have to inherit it? a female?

   Both male and female need two genes.

3. If the father is normal and the mother is heterozygous, how many normal female children are observed when the trait is sex-linked?

   All female children are normal.

4. If both parents are heterozygous, how many normal female children are observed if the trait is not sex-linked?

   There would be normal female children 75 percent of the time.

5. If both parents are heterozygous, how many female children with the disease (recessive trait) are observed if the trait is considered not to be sex-linked?

   There would be female children with the disease 25 percent of the time.

6. If the mother is heterozygous and the father is normal, how many female children with the disease (recessive trait) are observed if the trait is considered to be sex-linked?

   There are no female children with the disease.

7. Which inheritance pattern results in no females with the disease?

   Sex-linked diseases would not appear in a female.

8. If the father is normal and the mother is heterozygous, how many normal male children are observed when the trait is sex-linked?

   One-half of the male children would be normal.

9. If both parents are heterozygous, how many normal male children are observed if the trait is not sex-linked?

   If the gene is not sex-linked and both parents are heterozygous, there would be normal male children 75 percent of the time.

10. If both parents are heterozygous, how many male children with the disease are observed if the trait is not sex-linked?

    If the gene is not sex-linked and both parents are heterozygous, there would be male children with the disease 25 percent of the time.

11. If the mother is heterozygous and the father is normal, how many male children with the disease are observed if the trait is sex-linked?

    There would be male children with the disease 50 percent of the time.

12. Which inheritance pattern provides equal numbers of normal male children and male children with the disease?

    Sex-linked inheritance will provide equal numbers of normal males and males with the disease.

13. Write a short paragraph that explains how sex-linked traits are different from other inherited traits. Be sure to include such words as *genotype*, *phenotype*, *dominant*, *recessive*, and *carrier*.

    Sex-linked traits are inherited with the sex of the offspring, that is, sex chromosomes are carried only on the X sex chromosomes.

    The male genotype needs only one gene from the mother to display the phenotype whereas the female genotype requires two genes for the phenotype to display the characteristic.

    The female can be a carrier since she can carry the recessive gene without demonstrating the phenotype.

LESSON 14

Learning Activity 1.15: Mutation Situation

Scenario 1

- Is Manon in danger?

  Manon's problem is not life threatening.
- Will she have problems?

  Manon will have major social problems if her skin condition spreads over her whole body.
- If she gives birth to a baby in a few months, will her child have these skin rashes? Explain.

  Manon's baby will not have the same skin condition as her sex cells were not affected.

Scenario 2

- Will Patrick's children also be asthmatic?

  Patrick's children will not be asthmatic.
- What kind of problems do his children risk having? Why?

  Patrick's children run the risk of having three-nostril noses. This is because the germinal cells of his testicles were mutated, altering the sperm he will produce. However, his children will not run the risk of getting asthma because that mutation was limited to the somatic cells of his lungs and will not have an impact on his germinal cells.
- Can Patrick prevent having children with three nostrils? How could this mutation be an advantage to his children?

  Patrick cannot prevent some of his children from having three nostrils. This mutation could be an advantage if their sense of smell was greatly improved. There is a real need for this type of superior sense of smell.

Scenario 3

- Will Peter's children become musically talented as well? Explain.

  Peter's children will not have any more musical talent than any other children as the mutation is in nervous cells and not sex cells.
- Will his children necessarily have little musical talent? Explain.

  Peter's children will be much the same as their ancestors, as opposed to their father.

- Is there a way to produce offspring who would have Peter's musical mutation?

  Peter's musical mutation could be passed on to other generations if his sex cells underwent a chromosomal mutation that could be passed on.

Scenario 4

- Will the flying frog with antennae also be lazy?

  The flying frog with antennae will not be lazy as we assume that is a learned response.
- Will the frog be able to feed more easily than Freddy?

  The frog will certainly be able to feed more easily as he can fly after flies.
- Will Freddy produce more flying frogs with antennae?

  Freddy will produce more flying frogs, but the potential for antennae rested with his mating partner, not Freddy himself.

Scenario 5

- Are Yik and Yok identical twins?

  Yik and Yok are not identical twins since their genetic makeup is not identical.
- At birth, Yok is twice as heavy as Yik. Why?

  Yok is twice as heavy as Yik at birth since she has a hormonal imbalance and Yik doesn't.
- Will Yok's children be bigger than Yik's? Explain.

  Yik's children could be larger than Yok's since her sex cells were mutated and the mutation will be passed on to at least some of her children.

LESSON 17

Learning Activity 1.16: Reproduction Review

Multiple Choice

Circle the choice that best matches the question.

1. Which of the following is not part of the cell nucleus?
   a. nuclear membrane
   b. cell wall
   c. chromosomes
   d. nucleolus

2. Plant and animal cells differ in that
    a. plants have chromosomes and animals do not
    b. animals undergo mitosis and plants do not
    c. plants have a cell wall and animals do not
    d. animals have a cell nucleus and plants do not
3. Reproduction is necessary for life to continue. Which of the following types of reproduction would require meiosis?
    a. healing and tissue repair
    b. growth
    c. sexual reproduction of the organism
    d. all of the above
4. Sperm and egg cells combine to form a
    a. zygote
    b. gonad
    c. haploid cell
    d. homologous pair
5. A somatic cell is a
    a. sex cell
    b. diploid cell
    c. body cell
    d. daughter cell
6. Bacteria reproduce sexually by conjugation. In conjugation, the bacteria exchange genetic information using packets of genetic material called
    a. plasmids
    b. bridges
    c. chromatins
    d. cytoplasm
7. The interphase is a part of
    a. mitosis
    b. cell division
    c. the cell cycle
    d. cytokinesis

8. Yeast reproduce by
    a. sporulation
    b. mitosis
    c. sexual reproduction
    d. budding

9. The ovary contains corpus luteum during the later part of ovulation. Its function is
    a. to provide hormones if pregnancy begins
    b. to push the egg cell out of the ovary
    c. to move the egg cell into the uterus
    d. to remove the egg cell if fertilization did not take place

10. The female hormone responsible for preparing the uterus for the egg cell is called
    a. androgen
    b. testosterone
    c. estrogen
    d. progesterone

11. Which of the following is/are true of sperm?
    a. produced in seminiferous tubules
    b. has a tail for moving
    c. located in semen
    d. all of the above

12. During the first eight weeks of pregnancy, the developing child is called
    a. a zygote
    b. an embryo
    c. a fetus
    d. a newborn

13. The sex of a child is determined
    a. at fertilization
    b. by the father
    c. by XY chromosomes
    d. all of the above

14. A single trait in an offspring
    a. can only come from a dominant gene
    b. must be present in both genes from the parents
    c. cannot come from recessive genes from both parents
    d. can only come from the male gamete

15. Sex-linked traits
    a. are located on the Y chromosome
    b. can be passed from father to son
    c. can be passed from mother to son
    d. are no different from ordinary traits

16. A mother with a homozygous recessive trait for straight hair ("c" since curly hair is dominant) would
    a. be labelled "cc" for the mother genotype
    b. produce 25 percent curly-haired offspring with a heterozygous curly-haired father
    c. yield only heterozygous offspring
    d. all of the above

17. An allele
    a. is another name for a chromosome
    b. determines the sex of the offspring
    c. is a variation of a gene relating to the same characteristic
    d. is responsible for determining sex-linked traits

Use the Punnett square below to answer the next two questions.

		Father	
		D	d
Mother	d	Dd	dd
	d	Dd	dd

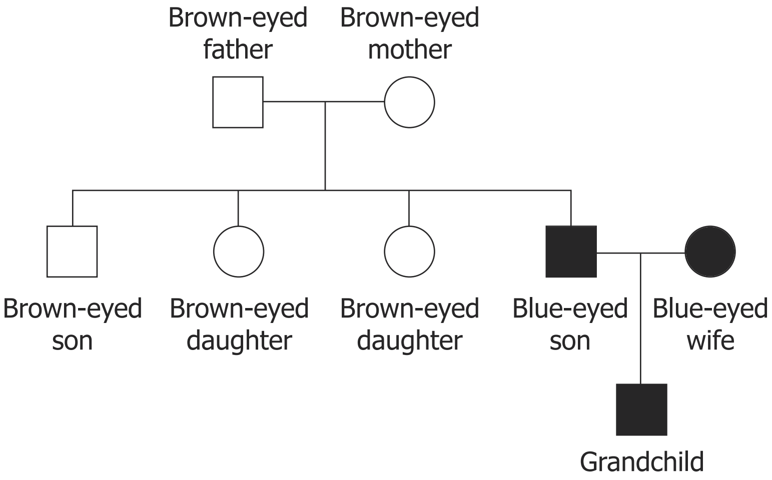
A father has a dominant gene "D" for dark hair and a recessive gene "d" for light hair.

A mother has two recessive genes for light hair.

18. The father is
    a. homozygous light hair
    b. heterozygous dark hair
    c. heterozygous light hair
    d. homozygous dark hair

19. The offspring will be
    a. 100 percent heterozygous dark hair
    b. 50 percent heterozygous dark hair
    c. 25 percent homozygous light hair
    d. 75 percent heterozygous dark hair

20. Using the pedigree below and knowing blue eyes come from a recessive gene, choose the true statement.



    a. There is a 25 percent chance of a blue-eyed grandchild.
    b. There is a 50 percent chance of a blue-eyed grandchild.
    c. There is a 75 percent chance of a blue-eyed grandchild.
    d. There is a 100 percent chance of a blue-eyed grandchild.

Questions

1. Match the terms in the left column with the descriptions in the right column.

   c cell membrane
   d nucleus
   e cytoplasm
   a Golgi complex
   b chromosome

   a. packages and stores proteins
   b. contains all the information needed for cell reproduction
   c. controls transport of materials in and out of the cell
   d. command centre of the cell
   e. filled with organelles that perform the cell functions

2. State the three main parts to the cell theory.

   a. **All living things are made of one or more cells.**
   b. **The cell is the functional unit of life.**
   c. **All living cells come from pre-existing cells.**

3. Cell division is a common method for reproduction in living things. Describe what happens in cell division, using the following words: *cell cycle*, *mitosis*, *cytokinesis*, and *interphase*.

   The cell cycle has two parts—cell division and interphase. Cell division takes place through mitosis, where the cell nucleus duplicates itself, and cytokinesis, where the cytoplasm is divided into two parts. After cell division takes place, the cell stays in interphase where it matures and chromosomes duplicate themselves.

4. State the name given to the type of asexual reproduction for the following:

   a. bacteria **binary fission**
   b. moulds **sporulation**
   c. yeast **budding**
   d. starfish **regeneration**
   e. plants **vegetative propagation**

5. Each body cell in a certain organism has 28 pairs of chromosomes.

   a. What is the diploid number of chromosomes for this organism? **28 pairs or 56**
   b. What is the haploid number of chromosomes for this organism? **28**
   c. How many chromosomes would a male sperm have? **28**
   d. How many chromosomes would a female egg have? **28**
   e. How many chromosomes would there be after the sperm and egg unite to form a zygote? **28 pairs (or 56)**

6. Fill in the blanks with the appropriate term from this list: *1n*, *2n*, *meiosis*, *mitosis*.

   When sexual reproduction takes place,

   a. the male sperm reproduce through a process called **meiosis**

   b. in a human, the female egg would contain **1n** chromosomes

   c. once the egg and sperm unite to form a zygote, the remaining cell reproduction is through **mitosis**

7. Match the terms in the left column with the descriptions in the right column.

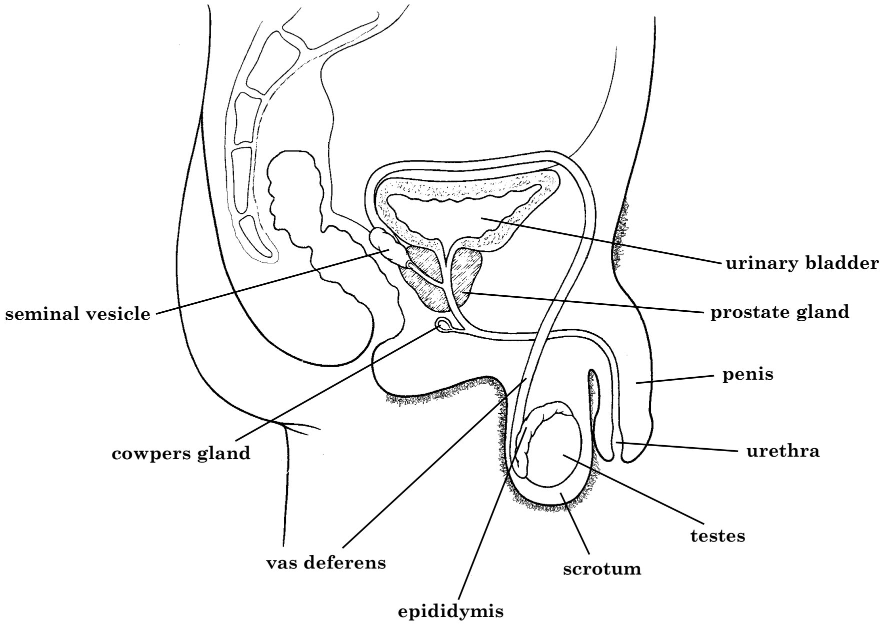
   c sperm
   a stigma
   e egg
   d pollen
   b gonad

   a. part of female sex organ in plants
   b. sex organ in females and males
   c. male sex cell
   d. male sex cell in plants
   e. female sex cell

8. Complete the contrast table shown below

	Asexual Reproduction	**Sexual Reproduction**
Number of parents	**1 parent**	**2 parents**
How offspring compare to parents	**Identical to parent**	**Combination of both parents based on sharing of chromosomes**
Ability to respond to new environment	**Cannot respond to change in environment**	**Responds to environment because of genetic variations that can occur, increasing reproductive success**

9. Fill in the blanks to label the diagram below.



9. Match the terms in the left column with the descriptions in the right column.

c scrotum
h vas deferens
e testes
l endometrium
i epididymis
f semen
j fertilization
b testosterone
a hypothalamus
d estrogen
k ovulation
g ovary

a. controls the release of sex hormones
b. male sex hormone
c. keeps sperm at constant temperature
d. female sex hormone
e. male sex organ that produces sperm
f. a fluid that accompanies sperm and helps it travel
g. female gonad
h. a duct that carries sperm to the urethra
i. a place where sperm mature and are stored
j. occurs when a sperm comes in contact with an egg
k. the process of providing a mature egg cell for fertilization
l. provides nourishment for the developing embryo

11. Name three indicators of puberty in a male.
    a. **onset of sperm production**
    b. **sexual organs grow and develop**
    c. **voice changes; muscle and bone grow**

12. Describe the formation of an egg cell and its movement to prepare for fertilization. Use the following terms: *uterus*, *ovary*, *oviduct* (*fallopian tube*), *endometrium*.

    An egg cell begins to form in the ovary. Once formed, the egg moves into the fallopian tube where it is transported into the uterus where it can be fertilized. The fertilized egg will move into the endometrium and the process of development begins.

13. What takes place during
    a. ovulation?

       A follicle gives rise to an egg cell that breaks through the ovary wall to deposit a mature egg cell into the oviduct. The process of releasing an egg into the oviduct is called ovulation.

    b. menstruation?

       If there is no fertilization and no pregnancy is taking place, the egg cell and the endometrium are discarded through menstruation. Menstruation is a flow of liquids that clean out the egg and endometrium that have not been used for embryo development.

14. Place the following terms in order from smallest to largest: *chromosome*, *DNA*, *gene*.

    smallest **DNA**
    middle **gene**
    largest **chromosome**

15. The gene for yellow colour (Y) in peas is dominant and the gene for green colour (y) is recessive. Plant A that has one yellow dominant gene and one green recessive gene is crossed with Plant B that has two green recessive genes.
    a. Show the colour genotype for each plant.

       Plant A = yellow Yy, Plant B = green yy

    b. What is the phenotype for each plant?

       Plant A = yellow, Plant B = green

c. Complete the Punnett square for the offspring of the cross between the two plants.

Plant A

Plant B

	Y	y
y	**Yy**	**yy**
y	**Yy**	**yy**

d. What percentage of the time will the offspring be

   i. green **50%**

   ii. yellow **50%**

e. List any homozygous offspring.

   Fifty percent of the time there will be homozygous green plants (yy).

16. The sex-determining chromosomes are the X and Y chromosomes.

   a. What is the X,Y chromosome pair for

      i. a male? **XY**

      ii. a female? **XX**

   b. Draw a Punnett square showing the possible sex of the offspring for a mother and father.

Father

Mother

	X	**Y**
X	**XX**	**XY**
X	**XX**	**XY**

   c. According to your Punnett square, what percentage will be male and female offspring?

      i. Male **50% (XY)**

      ii. Female **50% (XX)**

d. A mother has a recessive gene for colour-blindness on the X chromosome. Will she pass the recessive gene to her

   i. daughter? ___**No**___

   ii. son? ___**Yes**___

17. Teddy the bear has a strong desire to eat gumdrops. Whenever he can get them, he will overdose. Teddy also loves to sunbathe. The gumdrops have created a mutation in his body cells that result in an oversized left ear. His sunbathing has resulted in a mutation in his sex cells which have a tendency to cause superior guitar playing.

    a. Could any of his offspring have oversized left ears? ___**No**___

    b. Could any of his offspring be superior guitar players? ___**Yes**___

    c. Explain your answers to (a) and (b).

    A large left ear for Teddy is body cell mutation that is not passed on to his offspring. The sex cell mutation (superior guitar playing) can be passed on to the next generation.

18. Name two environmental factors responsible for genetic mutations.

    a. **Exposure to the ultraviolet portion of the sun's rays is one environmental factor.**

    b. **Air pollution, chemical pollution from agricultural sprays, or manufacturing processes can also be responsible for genetic mutations. There are many more.**

19. What is a chromosomal mutation?

    A chromosomal abnormality or mutation can occur during meiosis or mitosis. During the replication process, part of a chromosome, such as a gene, can be lost, changed, or mixed up.

20. Name one way that Canada has developed genetic technology.

    Canada has played a leading role in genetically modified food. Canada has also worked on the human genome project.

GRADE 9 SCIENCE (10F)

Module 2

Atoms and Elements

This module contains the following:

MODULE 2
ATOMS AND ELEMENTS

Introduction

You can find chemicals and observe chemical reactions taking place around you at all times. The boiling of an egg, the driving of a car, and the dying of your hair are all examples of chemical reactions.

You first began your chemistry journey in Grade 5 when you learned about the properties and changes that substances undergo and in Grade 7 when you learned about the Particle Theory of Matter.

In this module you will learn about chemical properties and reactions, models of the atom, and the periodic table. This will give you a firm understanding of the basics of chemistry that you will use again in Grade 10 Science.

Learning Activities

There are several learning activities placed throughout this module, which will help you practise using the information you will learn. The answer keys for each of these learning activities are found in Module 2 Learning Activity Answer Key. Check the answer key carefully and make corrections to your work.

A **computer with Internet access** would be beneficial throughout the course. Additional support materials for the course are provided on websites that are listed. All of the URLs listed in this course were working when this course was written, but, since Internet sites come and go, you might find that some of these sites are no longer active or appropriate. If that happens, you could use a search engine (e.g., www.google.ca) to find the information that you are looking for.

Assignments in Module 2

When you complete Module 2, you will submit your Module 2 assignments, to the Distance Learning Unit either by mail or electronically through the learning management system (LMS). The staff will forward your work to your tutor/marker.

Lesson	Assignment Number	Assignment Title
5	Assignment 2.1	Atomic Timeline
8	Assignment 2.2	Subatomic Particles and the Bohr Model
12	Assignment 2.3	Chemical Reactivity on the Periodic Table
17	Assignment 2.4	Chemical and Physical Change Experiments

You must complete one of four hands-on experiments in Assignment 2.4. Read over each option in that assignment (Lesson 17) and choose the option that most interests you. Start looking for these materials now in order to be prepared for the assignment.

Option 1: Salt and Water

- water
- salt
- teaspoon
- glass tumbler
- stir stick
- magnifying glass

Option 2: Effervescent Antacid Tablets and Water

- stir stick
- magnifying glass
- water
- glass tumbler
- 1 effervescent tablet
- scraping tool

Option 3: Candle Wax and Heat

- candle
- candle holder
- matches

Option 4: Steel Wool and Vinegar

- steel wool pad
- thermometer
- vinegar
- airtight jar (large enough to hold the thermometer)
- small cup

You will find instructions on how to hand in these assignments at the end of the module.

These assignments will be worth a portion of the 75 percent of the total marks you will receive for assignments in this course.

Notes

LESSON 1: SAFETY PROCEDURES

Lesson Focus

After completing this lesson, you will be able to

☐ describe safety procedures to be followed in the laboratory

Safety Procedures

Your school laboratory, like your kitchen, does not need to be dangerous. In both places, understanding how to use materials and equipment and following proper procedures will help you to avoid accidents. The activities in this course have been tested and are safe, as long as they are done with proper care.

For lab assignments in this course, be sure to check with an adult before beginning. Follow the guidelines and general safety rules listed below.

Students must

- not perform laboratory experiments at home unless directed to do so
- report to the teacher all accidents and hazards (no matter how minor), including broken equipment, damaged defective facilities, and suspicious-looking material
- learn the location of safety goggles, protective aprons, heat- resistant gloves, fire extinguisher, and fire blankets
- inform the teacher of any allergies, medical conditions, or other physical problems
- obtain the teacher’s approval before carrying out an experiment or before designing an experiment
- clear the laboratory bench of all material except that being used in the activity
- wear protective clothing (a lab apron or a coat) and closed shoes during activities involving equipment or materials (long hair must be tied back)
- wear safety goggles when using hazardous materials and when heating materials

- avoid tasting or touching any material, unless instructed to do so
- not chew gum, eat, or drink in the laboratory
- read and understand all labels on containers
- double-check the label when taking something from a bottle or container to be sure it is exactly what is needed
- not pour liquids while holding the containers close to the face
- clean up any spilled water and chemicals
- not return unused chemicals to original containers
- not pour unused chemicals down the drain unless instructed to do so
- use electric hotplates whenever possible (use flames only when instructed to do so)
- wear safety goggles and use hand protection if required when heating materials
- use a test tube holder when heating a test tube over a flame (hold the test tube at an angle and facing away from anyone; move it gently through the flame to heat contents evenly)
- apply water immediately if suffering from a burn
- make sure hands are dry when handling electrical cords and plugs (keep electrical cords, plugs, and sockets away from water)
- make sure electrical cords are not placed where anyone can trip over them
- always cut away from the body when using a scalpel
- watch for sharp or jagged edges on all objects
- place broken or waste glass only in special containers
- follow the teacher’s instruction when dissecting
- clean all equipment before putting it away
- wash hands thoroughly using soap and warm water after all lab activities
- not take any equipment, materials, chemicals, or biological specimens out of the laboratory

Summary

Whenever you are working in a laboratory situation (whether at home or at school) it is important to following proper safety procedures. In the next lesson you will learn about symbols which can help alert you to laboratory dangers.

LESSON 2: WHAT IS WHMIS?

Lesson Focus

After completing this lesson, you will be able to

☐ appreciate the need for the Workplace Hazardous Materials Information System (WHMIS)
☐ identify the WHMIS warning symbols
☐ describe the contents of a typical Material Safety Data Sheet (MSDS)

Key Words

- WHMIS
- Material Safety Data Sheet (MSDS)
- WHMIS symbols
- Hazardous Household Product Symbols (HHPS)

Standardization of symbols has been put in place to make understanding warnings safety precautions easier.

What Is WHMIS?

The Workplace Hazardous Materials Information System (WHMIS) is the name given to the legislation covering hazardous materials used in Canadian workplaces. The legislation was implemented by the federal, provincial, and territorial governments in 1988.

Exposure to hazardous materials may result in burns, rashes, cancer, and kidney and lung damage. Improper handling and storage could cause an explosion or a fire.

In 1986, the costs of accidents and ill health to Canadian workers was in the range of $600 million. WHMIS was implemented to reduce ill health caused by hazardous materials. In Canada, labour and industry worked together with government to introduce this legislation.

WHMIS is an information-based system that covers the use of hazardous materials in the workplace.

The supplier's responsibility is to

- ensure that hazardous materials are correctly labelled and are accompanied by **Material Safety Data Sheet (MSDS)—** see Figure 2.3 on page 14

The employer's responsibility is to

- maintain inventories of all hazardous materials
- ensure all hazardous materials are properly labelled
- display MSDS in the workplace
- develop education programs for employees

The employees' responsibility is to

- learn about hazardous products and the safe use and handling of these materials

Controlled Products

Hazardous materials (controlled products) covered by WHMIS are categorized into six classes.

- Class A: Compressed Gas
- Class B: Flammable and Combustible Material
- Class C: Oxidizing Material
- Class D: Poisonous and Infectious Material
- Class E: Corrosive Material
- Class F: Dangerously Reactive Material

Controlled products in schools include a wide variety of chemicals used by both teachers and maintenance staff. The manufacturer and supplier have the ultimate responsibility to determine if their product is a controlled product and supply proper labelling and an MSDS.

Chemical products covered under other legislation are not included under WHMIS. These are

- explosives
- cosmetics, drugs, and food
- radioactive materials
- consumer products subject to the Hazardous Products Act

Warning Symbols

Become familiar with the warning symbols that are placed on potentially dangerous substances both in workplaces and at home.

In the workplace

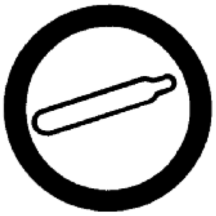
- **WHMIS symbols** (Figure 2.1) standardize the labelling of dangerous materials used in all workplaces, including laboratories and schools

In homes

- **Hazardous Household Product Symbols (HHPS)** (Figure 2.2) standardize the labelling of dangerous materials used in the home

You should be able to identify and understand the both the WHMIS and HHPS labels in order to take the necessary precautions with the materials that you handle.

Figure 2.1 *WHMIS Hazard Symbols**


Class A
compressed gas


Class B
flammable and
combustible material


Class C
oxidizing material


Class D1
poisonous and infectious material:
materials causing immediate and
serious toxic effects


Class D2
poisonous and infectious material:
material causing other toxic effects


Class D3
poisonous and infectious material:
biohazardous infectious material


Class E
corrosive material


Class F
dangerously reactive material

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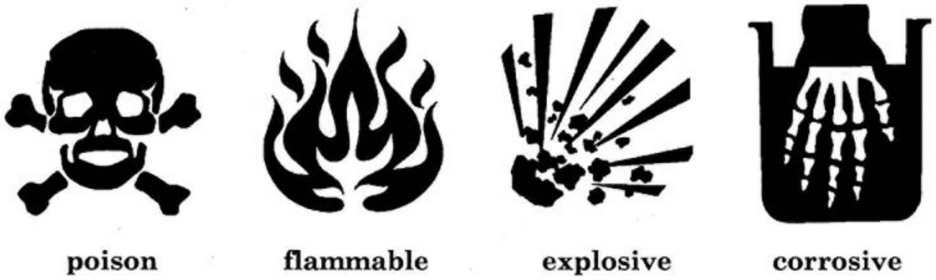
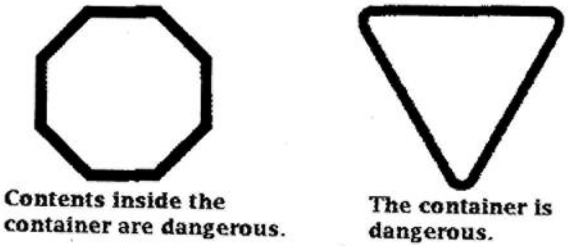
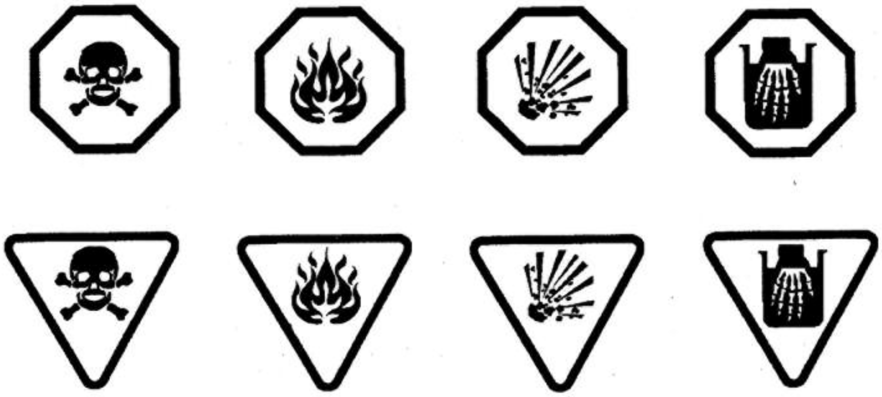
*Source: *WHMIS Classes, Divisions and Subdivisions and Corresponding Hazard Symbols.* Health Canada 2010. Reproduced with the permission of the Minister of Health, 2011.

Figure 2.2 ***Hazardous Household Products Symbols****



These four symbols may appear in the following shapes, used to distinguish between the contents of the container and the container itself.





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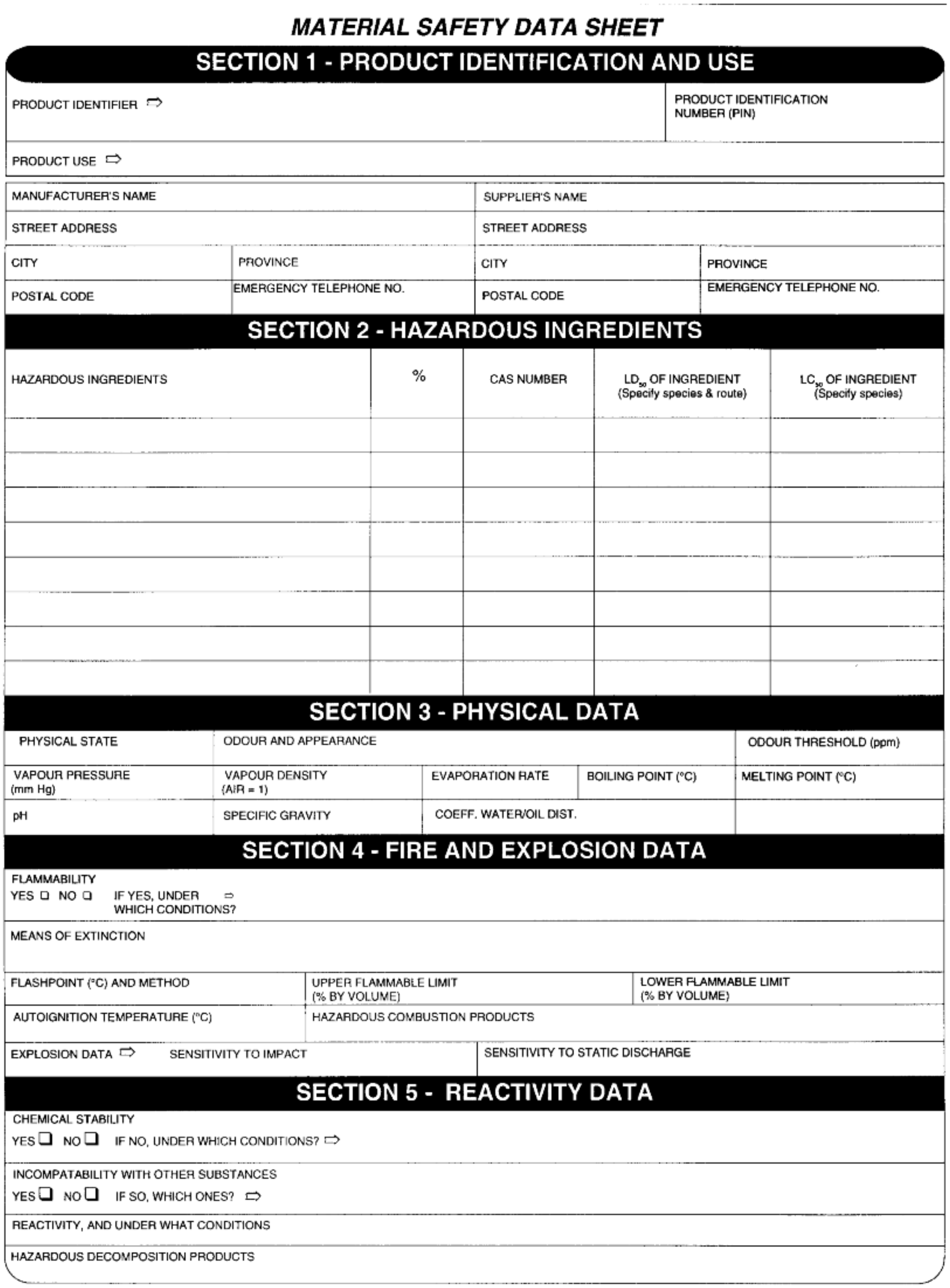
*Source: *Stay Safe – An Education Guide to Hazard Symbols.* Health Canada 2004. Reproduced with the permission of the Minister of Health, 2011.

Figure 2.3 **MSDS**



MATERIAL SAFETY DATA SHEET

SECTION 1 - PRODUCT IDENTIFICATION AND USE

PRODUCT IDENTIFIER ⇨
PRODUCT IDENTIFICATION NUMBER (PIN)
PRODUCT USE ⇨

MANUFACTURER'S NAME
STREET ADDRESS
CITY
PROVINCE
POSTAL CODE
EMERGENCY TELEPHONE NO.

SUPPLIER'S NAME
STREET ADDRESS
CITY
PROVINCE
POSTAL CODE
EMERGENCY TELEPHONE NO.

SECTION 2 - HAZARDOUS INGREDIENTS

HAZARDOUS INGREDIENTS	%	CAS NUMBER	LD_{50} OF INGREDIENT (Specify species & route)	LC_{50} OF INGREDIENT (Specify species)

SECTION 3 - PHYSICAL DATA

PHYSICAL STATE
ODOUR AND APPEARANCE
ODOUR THRESHOLD (ppm)
VAPOUR PRESSURE (mm Hg)
VAPOUR DENSITY (AIR = 1)
EVAPORATION RATE
BOILING POINT (°C)
MELTING POINT (°C)
pH
SPECIFIC GRAVITY
COEFF. WATER/OIL DIST.

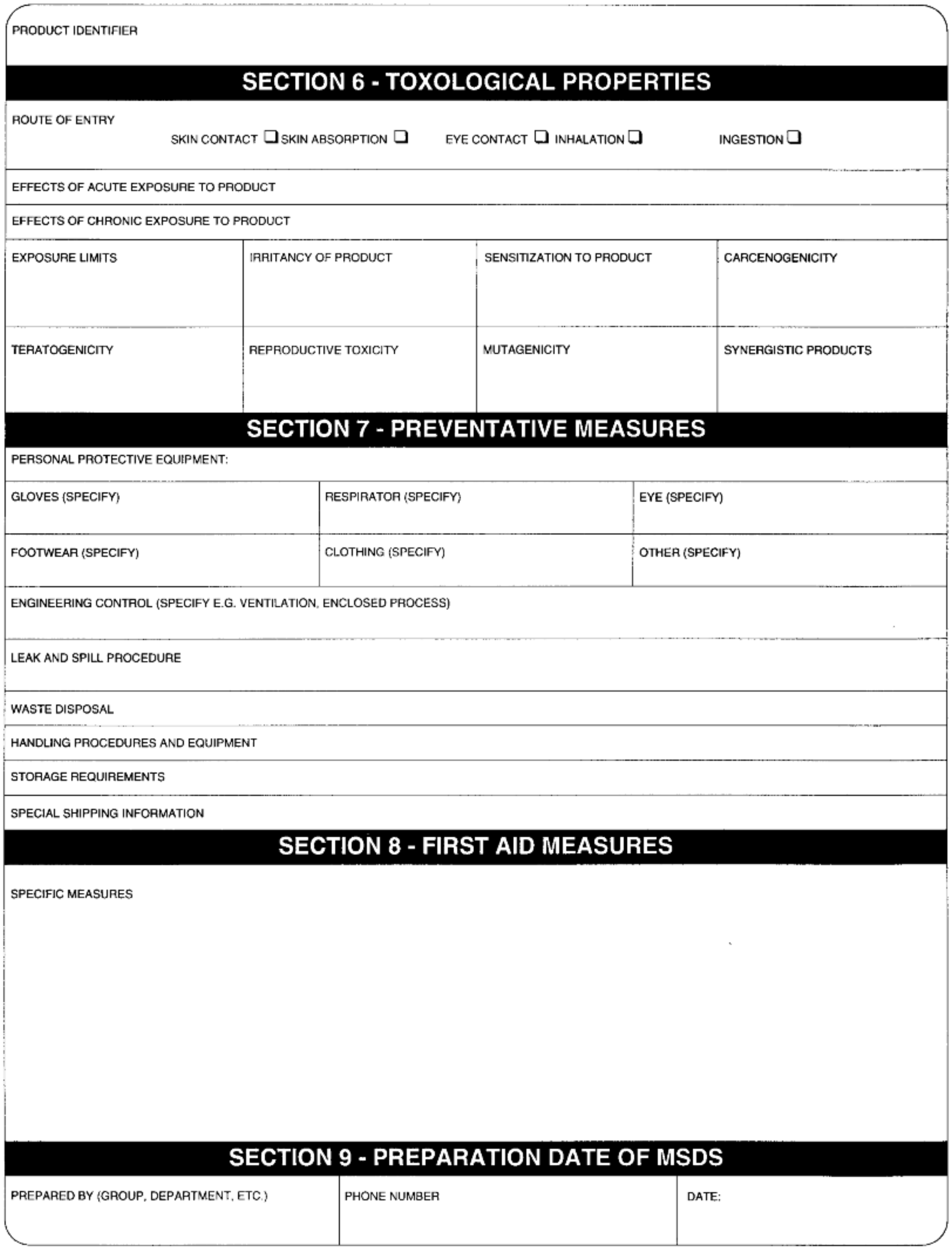
SECTION 4 - FIRE AND EXPLOSION DATA

FLAMMABILITY
YES ☐ NO ☐ IF YES, UNDER WHICH CONDITIONS? ⇨
MEANS OF EXTINCTION
FLASHPOINT (°C) AND METHOD
UPPER FLAMMABLE LIMIT (% BY VOLUME)
LOWER FLAMMABLE LIMIT (% BY VOLUME)
AUTOIGNITION TEMPERATURE (°C)
HAZARDOUS COMBUSTION PRODUCTS
EXPLOSION DATA ⇨ SENSITIVITY TO IMPACT
SENSITIVITY TO STATIC DISCHARGE

SECTION 5 - REACTIVITY DATA

CHEMICAL STABILITY
YES ☐ NO ☐ IF NO, UNDER WHICH CONDITIONS? ⇨
INCOMPATABILITY WITH OTHER SUBSTANCES
YES ☐ NO ☐ IF SO, WHICH ONES? ⇨
REACTIVITY, AND UNDER WHAT CONDITIONS
HAZARDOUS DECOMPOSITION PRODUCTS

Figure 2.3 **MSDS**



PRODUCT IDENTIFIER

SECTION 6 - TOXOLOGICAL PROPERTIES

ROUTE OF ENTRY

SKIN CONTACT ☐ SKIN ABSORPTION ☐ EYE CONTACT ☐ INHALATION ☐ INGESTION ☐

EFFECTS OF ACUTE EXPOSURE TO PRODUCT

EFFECTS OF CHRONIC EXPOSURE TO PRODUCT

EXPOSURE LIMITS	IRRITANCY OF PRODUCT	SENSITIZATION TO PRODUCT	CARCENOGENICITY
TERATOGENICITY	REPRODUCTIVE TOXICITY	MUTAGENICITY	SYNERGISTIC PRODUCTS

SECTION 7 - PREVENTATIVE MEASURES

PERSONAL PROTECTIVE EQUIPMENT:

GLOVES (SPECIFY)	RESPIRATOR (SPECIFY)	EYE (SPECIFY)
FOOTWEAR (SPECIFY)	CLOTHING (SPECIFY)	OTHER (SPECIFY)

ENGINEERING CONTROL (SPECIFY E.G. VENTILATION, ENCLOSED PROCESS)

LEAK AND SPILL PROCEDURE

WASTE DISPOSAL

HANDLING PROCEDURES AND EQUIPMENT

STORAGE REQUIREMENTS

SPECIAL SHIPPING INFORMATION

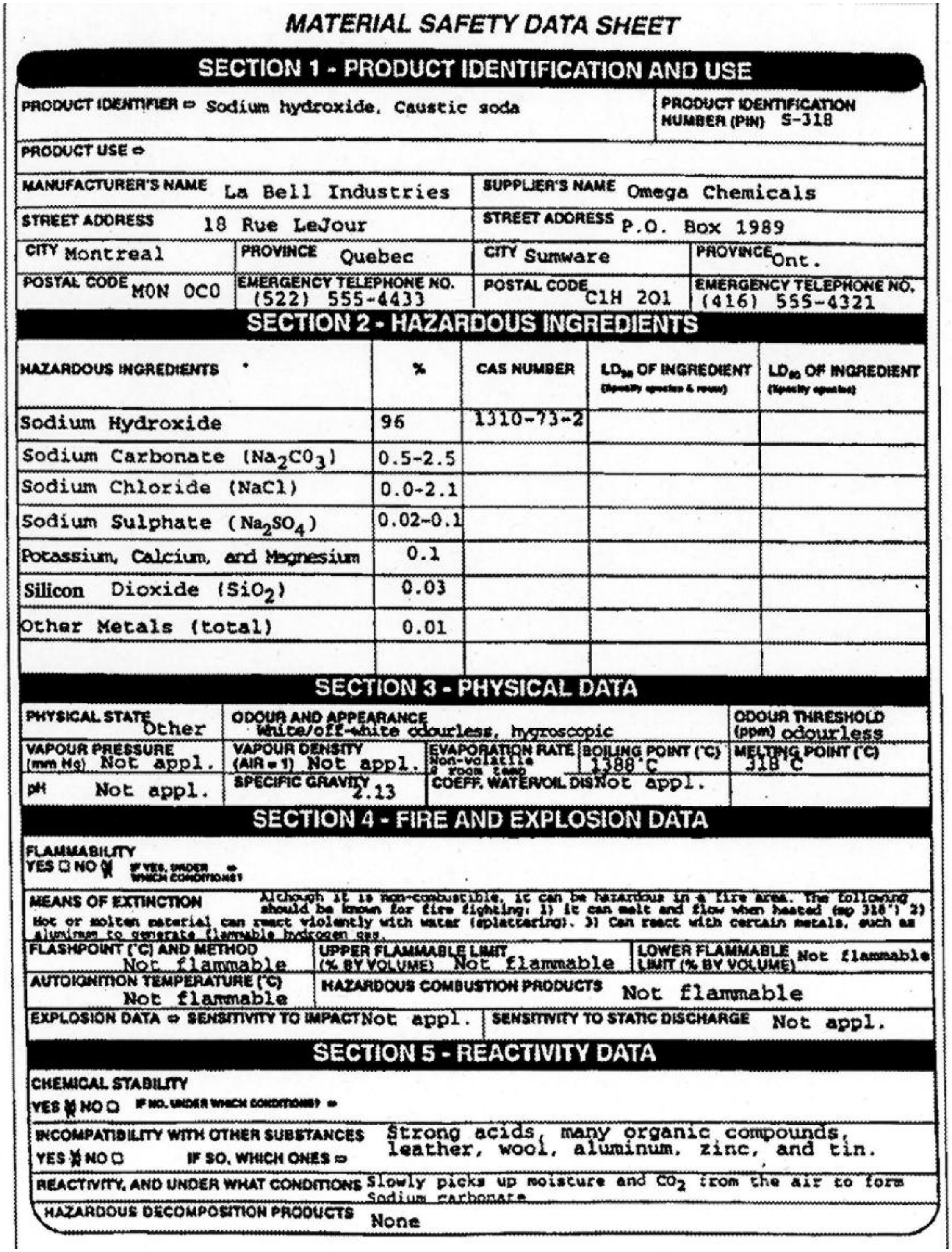
SECTION 8 - FIRST AID MEASURES

SPECIFIC MEASURES

SECTION 9 - PREPARATION DATE OF MSDS

PREPARED BY (GROUP, DEPARTMENT, ETC.)	PHONE NUMBER	DATE:

Figure 2.4 *Sample MSDS for Sodium Hydroxide*



MATERIAL SAFETY DATA SHEET

SECTION 1 - PRODUCT IDENTIFICATION AND USE

PRODUCT IDENTIFIER ⇨ Sodium hydroxide, Caustic soda

PRODUCT IDENTIFICATION NUMBER (PIN) S-318

PRODUCT USE ⇨

MANUFACTURER'S NAME La Bell Industries

STREET ADDRESS 18 Rue LeJour

CITY Montreal **PROVINCE** Quebec

POSTAL CODE M0N 0C0 **EMERGENCY TELEPHONE NO.** (522) 555-4433

SUPPLIER'S NAME Omega Chemicals

STREET ADDRESS P.O. Box 1989

CITY Sumware **PROVINCE** Ont.

POSTAL CODE C1H 201 **EMERGENCY TELEPHONE NO.** (416) 555-4321

SECTION 2 - HAZARDOUS INGREDIENTS

HAZARDOUS INGREDIENTS *	%	CAS NUMBER	LD_{50} OF INGREDIENT (Specify species & route)	LD_{50} OF INGREDIENT (Specify species)
Sodium Hydroxide	96	1310-73-2		
Sodium Carbonate (Na_2CO_3)	0.5-2.5			
Sodium Chloride (NaCl)	0.0-2.1			
Sodium Sulphate (Na_2SO_4)	0.02-0.1			
Potassium, Calcium, and Magnesium	0.1			
Silicon Dioxide (SiO_2)	0.03			
Other Metals (total)	0.01			

SECTION 3 - PHYSICAL DATA

PHYSICAL STATE Other

ODOUR AND APPEARANCE White/off-white odourless, hygroscopic

ODOUR THRESHOLD (ppm) odourless

VAPOUR PRESSURE (mm Hg) Not appl.

VAPOUR DENSITY (AIR = 1) Not appl.

EVAPORATION RATE Non-volatile @ room temp

BOILING POINT (°C) 1388°C

MELTING POINT (°C) 318°C

pH Not appl.

SPECIFIC GRAVITY 2.13

COEFF. WATER/OIL DIS Not appl.

SECTION 4 - FIRE AND EXPLOSION DATA

FLAMMABILITY
YES ☐ **NO** ☒ **IF YES, UNDER WHICH CONDITIONS? ⇨**

MEANS OF EXTINCTION Although it is non-combustible, it can be hazardous in a fire area. The following should be known for fire fighting: 1) it can melt and flow when heated (mp 318°) 2) Hot or molten material can react violently with water (splattering). 3) Can react with certain metals, such as aluminum to generate flammable hydrogen gas.

FLASHPOINT (°C) AND METHOD Not flammable

UPPER FLAMMABLE LIMIT (% BY VOLUME) Not flammable

LOWER FLAMMABLE LIMIT (% BY VOLUME) Not flammable

AUTOIGNITION TEMPERATURE (°C) Not flammable

HAZARDOUS COMBUSTION PRODUCTS Not flammable

EXPLOSION DATA ⇨ SENSITIVITY TO IMPACT Not appl.

SENSITIVITY TO STATIC DISCHARGE Not appl.

SECTION 5 - REACTIVITY DATA

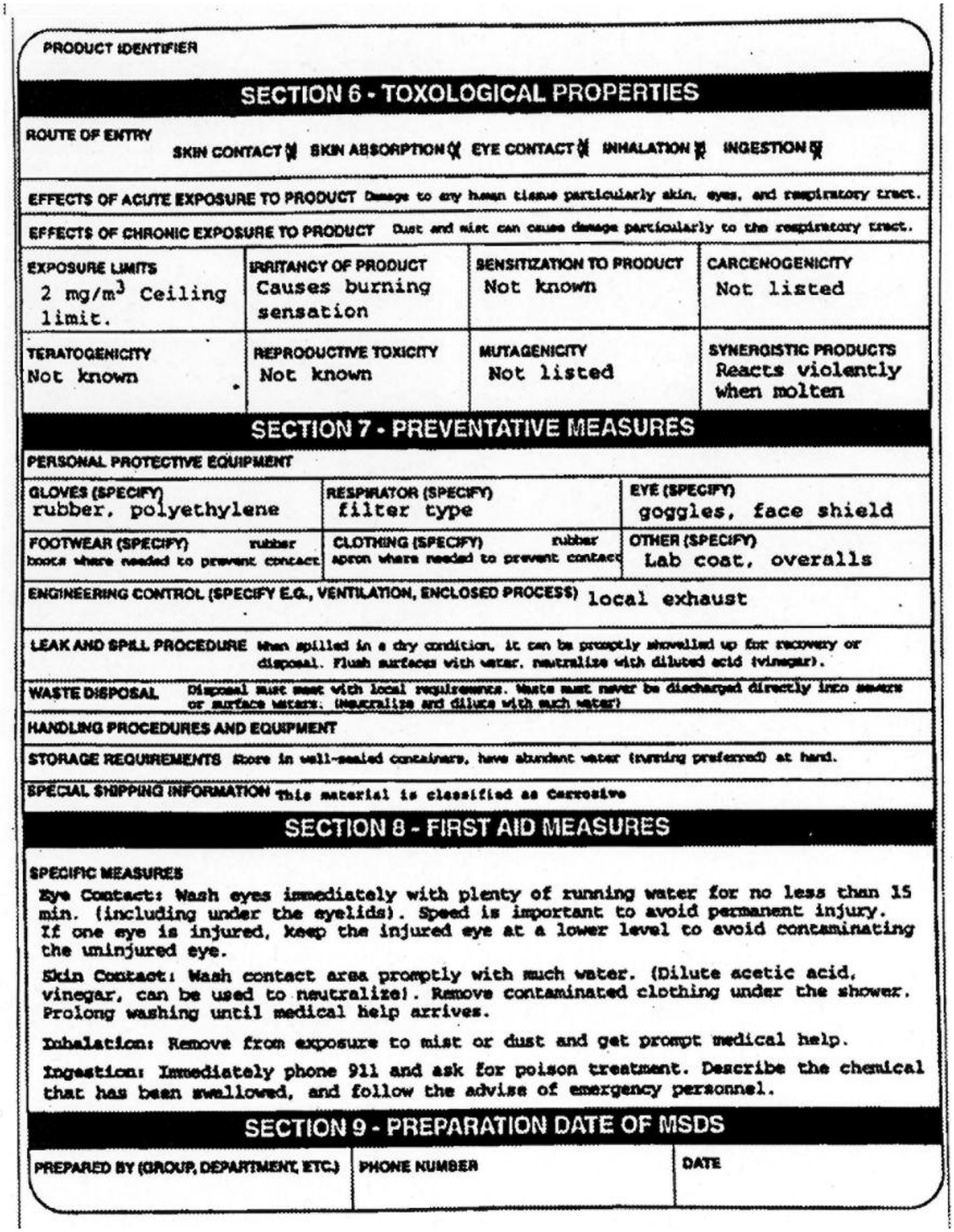
CHEMICAL STABILITY
YES ☒ **NO** ☐ **IF NO, UNDER WHICH CONDITIONS? ⇨**

INCOMPATIBILITY WITH OTHER SUBSTANCES
YES ☒ **NO** ☐ **IF SO, WHICH ONES ⇨** Strong acids, many organic compounds, leather, wool, aluminum, zinc, and tin.

REACTIVITY, AND UNDER WHAT CONDITIONS Slowly picks up moisture and CO_2 from the air to form Sodium carbonate

HAZARDOUS DECOMPOSITION PRODUCTS None

Figure 2.4



PRODUCT IDENTIFIER

SECTION 6 - TOXOLOGICAL PROPERTIES

ROUTE OF ENTRY SKIN CONTACT ☒ SKIN ABSORPTION ☒ EYE CONTACT ☒ INHALATION ☒ INGESTION ☒

EFFECTS OF ACUTE EXPOSURE TO PRODUCT Damage to any human tissue particularly skin, eyes, and respiratory tract.

EFFECTS OF CHRONIC EXPOSURE TO PRODUCT Dust and mist can cause damage particularly to the respiratory tract.

EXPOSURE LIMITS 2 mg/m^3 Ceiling limit.	IRRITANCY OF PRODUCT Causes burning sensation	SENSITIZATION TO PRODUCT Not known	CARCENOGENICITY Not listed
TERATOGENICITY Not known	REPRODUCTIVE TOXICITY Not known	MUTAGENICITY Not listed	SYNERGISTIC PRODUCTS Reacts violently when molten

SECTION 7 - PREVENTATIVE MEASURES

PERSONAL PROTECTIVE EQUIPMENT

GLOVES (SPECIFY) rubber, polyethylene	RESPIRATOR (SPECIFY) filter type	EYE (SPECIFY) goggles, face shield
FOOTWEAR (SPECIFY) rubber boots where needed to prevent contact	CLOTHING (SPECIFY) rubber apron where needed to prevent contact	OTHER (SPECIFY) Lab coat, overalls

ENGINEERING CONTROL (SPECIFY E.G., VENTILATION, ENCLOSED PROCESS) local exhaust

LEAK AND SPILL PROCEDURE When spilled in a dry condition, it can be promptly shovelled up for recovery or disposal. Flush surfaces with water, neutralize with diluted acid (vinegar).

WASTE DISPOSAL Disposal must meet with local requirements. Waste must never be discharged directly into sewers or surface waters. (Neutralize and dilute with much water)

HANDLING PROCEDURES AND EQUIPMENT

STORAGE REQUIREMENTS Store in well-sealed containers, have abundant water (running preferred) at hand.

SPECIAL SHIPPING INFORMATION This material is classified as Corrosive

SECTION 8 - FIRST AID MEASURES

SPECIFIC MEASURES

Eye Contact: Wash eyes immediately with plenty of running water for no less than 15 min. (including under the eyelids). Speed is important to avoid permanent injury. If one eye is injured, keep the injured eye at a lower level to avoid contaminating the uninjured eye.

Skin Contact: Wash contact area promptly with much water. (Dilute acetic acid, vinegar, can be used to neutralize). Remove contaminated clothing under the shower. Prolong washing until medical help arrives.

Inhalation: Remove from exposure to mist or dust and get prompt medical help.

Ingestion: Immediately phone 911 and ask for poison treatment. Describe the chemical that has been swallowed, and follow the advise of emergency personnel.

SECTION 9 - PREPARATION DATE OF MSDS

PREPARED BY (GROUP, DEPARTMENT, ETC.)	PHONE NUMBER	DATE

Learning Activity 2.1: Safety Procedures

1. Complete the following chart to identify the WHMIS symbols* (fill in the blank squares).


Class A


Class D
Division 1


Class D
Division 3


Class B


Class D
Division 2


Class E


Class C


Class F

continued

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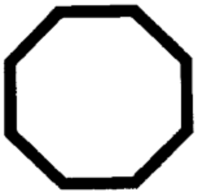
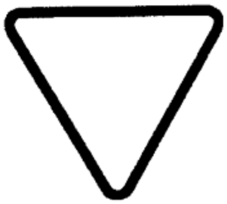
*Source: *WHMIS Classes, Divisions and Subdivisions and Corresponding Hazard Symbols.* Health Canada 2010. Reproduced with the permission of the Minister of Health, 2011.

Learning Activity 2.1 (continued)

2. Label the following hazardous household product symbols.*





3. Why should you never eat or drink from lab glassware?
4. Why is it unsafe to remove your goggles before the end of a lab period even though you have completed your experiment or investigation?
5. From the supplied MSDS on pages 14 and 15 (Figure 2.4), answer the following questions:
    a. What procedure should be used to clean up leaks or spills of sodium hydroxide?
    b. What first aid measures should be taken if sodium hydroxide gets in the eyes?
    c. Is it safe to store sodium hydroxide in a tin container? Why or why not?

Check the answer key.

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*Source: *Stay Safe – An Education Guide to Hazard Symbols.* Health Canada 2004. Reproduced with the permission of the Minister of Health, 2011.

Summary

WHMIS, MSDS, and HHPS are all commonly used methods to display safety information at school, work, and at home. It is important to look for safety precautions before working with any new product.

LESSON 3: SCIENCE IN ANCIENT TIMES

Lesson Focus

After completing this lesson, you will be able to

☐ describe the historical ideas and models that furthered our understanding of matter
☐ describe how scientific evidence supports the existence of elements
☐ define element and understand its relationship to the concept of matter
☐ describe some properties of substances

Online Resources

The following websites provide information about chemistry.

- Rader's Chem 4 Kids
  www.chem4kids.com/
- Oracle Education Foundation
  http://library.thinkquest.org/10429/low/matter/matter.htm

Key Words

- matter
- alchemist
- pure substance
- hypothesis

Early Developments

Science in Europe originated with the Greek philosophers. These people lived in a time when carefully constructed arguments and logical thought were highly valued. Science gradually evolved for 2000 years and then exploded in the eighteenth century as scientists used tools and methods that changed the process of science.

This lesson examines some of the great scientists and their contributions to understanding the world. As you increase your understanding, you are able to predict the behaviour and use of available materials.

Learning the history of science is important because it demonstrates the dynamic nature of science, and how it grows and develops constantly.

Science involves people who share what they have discovered to allow advancement of ideas and understanding of the world.

Use a journal to jot down ideas, ask questions, and develop concepts. Many great scientists wrote in journals, using them as personal encyclopedias of experience as their understanding of nature increased. People keep journals for many reasons. Journals help you to take note of the things around you.

Science in Ancient Times

Since ancient times, people have tried to understand and explain natural surroundings by measuring and categorizing. Greek philosophers, for example, relied more on logical argument and less on careful observation because of the few tools of observation available to them. They did not have scales, telescopes, and microscopes. Although they developed many good theories, ones that are accepted today as truth, they also developed incorrect theories that contradict modern science.

Two philosophers, living around 450 to 400 BCE, developed opposite viewpoints about matter. Empedocles stated that **matter** consisted of four elements: earth, air, water, and fire. Democritus stated that matter consisted of particles that, at some point, could not be broken down further. He called these particles “atoms” from the Greek atomos, which means uncuttable or incapable of being further divided. Today matter can be described as anything that has mass and takes up space.

Scientists today would claim that Democritus was correct. Aristotle, a highly respected philosopher, supported Empedocles. As a result of the respect that people had for Aristotle, his support of the four elements theory was accepted for 2000 years.

The Middle Ages

Scientists overcame the misconception that matter is composed of earth, air, water, and fire. In the Middle Ages, **alchemists** and scientists began to use experiments to develop their understanding of matter.

Alchemists searched for the philosopher's stone, which they thought would give them an understanding of every aspect of life (including science). They believed it was a stone of perfection that would transform lead into gold.

In 1699, Hennig Brandt, an alchemist from Hamburg, distilled urine to form a pure substance. While Brandt actually isolated an element, he never understood the implications of this experiment. Brandt had entered into the experiment with preconceptions that clouded his ability to think along new lines. (When doing science experiments, remember to be open to new ideas.)

Robert Boyle (1627–1691) was the first scientist to describe matter existing as an element. Boyle's own words described an element: "I mean by element, certain single unmingled bodies." Boyle's description of an element is also a description of a **pure substance** to be "un-mingled" with other substances.

Industrial Revolution

The scientific revolution, linked with the industrial revolution, created an explosion of scientific thought and experimentation. The development of tools of observation and measurement (microscopes, telescopes, balances, and gauges) allowed scientists to measure accurately. The scientific revolution took place in the late 1700s, and several scientists helped develop an understanding of the properties of elements.

Henry Cavendish isolated hydrogen in 1766 ("un-mingled" it). Cavendish knew he had produced a flammable gas, lighter than air, but he did not recognize it as an element.

Daniel Rutherford and Karl Wilhelm Scheele isolated nitrogen in 1772.

Karl Wilhelm Scheele isolated chlorine in 1774.

Joseph Priestley isolated oxygen in 1774. Priestley prepared oxygen by heating mercury oxide. The process produced pure oxygen and pure mercury. Priestley did not understand the importance of isolating oxygen, as the concept of matter existing as an element had not yet been developed.

Antoine Lavoisier recognized oxygen as an element. He was the first person to define an element as the final form that cannot be broken down further by chemical reactions. Lavoisier produced water by burning hydrogen in oxygen. Lavoisier is considered the founder of modern chemistry. Isaac Newton is associated mainly with physics and the laws of gravity, but he also conducted chemistry experiments. He repeated Boyle's experiments and he popularized Democritus's atomic theory.

Learning Activity 2.2: Science in Ancient Times

Use a textbook and any other resource material to answer these questions.

1. What is an element according to
   a. Empedocles
   b. Boyle
   c. Lavoisier
2. Describe how Priestley prepared oxygen.
3. Design and describe an experiment to demonstrate that fire is not an element.

Check the answer key.

Summary

- Early scientists were hampered by a lack of tools and methods of checking **hypotheses** (tentative theories that have not yet been proven).
- In the industrial revolution, the development of tools and increased emphasis on experimenting provided scientists with evidence that led them to understand the nature of matter. The four elements—air, water, fire, and earth—were, in fact, not elements (i.e., fundamental parts of matter).
- Cavendish, Priestley, and Lavoisier isolated gases that they were unable to break down further by chemical means. They considered them fundamental materials or pure substances. Water was no longer considered an element because combining hydrogen and oxygen could produce it.
- In the next four lessons, you will study how these historical developments have lead to our current understanding of atoms and elements.

Lesson 4: Dalton’s Atomic Theory

Lesson Focus

After completing this lesson, you will be able to

☐ describe the changes in scientists’ understanding of the structure of the atom from Dalton to Rutherford

☐ state Dalton’s description of the structure of the atom

☐ describe Thomson’s contribution to understanding the structure of atoms

☐ describe Rutherford’s contribution to understanding the structure of atoms

☐ use diagrams to illustrate the progression of understanding of the structure of the atom

Key Words

- properties
- atomic theory
- electron
- subatomic
- alpha particle
- nucleus
- proton

Online Resources

The following websites provide information about the scientists who furthered our understanding of the atom.

- Access Excellence. National Health Museum.
  www.accessexcellence.org/AE/AEC/CC/historical_background.html
  This site offers a brief history of Ernest Rutherford.

- AIP Center for History of Physics
  www.aip.org/history/electron/. This site offers information about J. J. Thomson and the importance of the electron.

In the previous lesson you learned about the history of matter, which has led to our current understanding about elements and atoms. In this lesson we will further explore the development of the model of the atom.

Structure of the Atom

Although much was known about characteristic **properties**, (chemical or physical characteristics) little was known about atomic structure. Scientists looked for clues as to the structure of the atom.

Lavoisier demonstrated the difference between elements and non-elements. Scientists discovered and used characteristic properties of elements. Newton stated his understanding of the structure of matter, while John Dalton added his understanding of the structure of the atom.

Dalton's interest in meteorology (the study of weather and its causes) led him to investigate gases. His research resulted in the belief that pure substances are made of individual particles (Democritus called them atoms).

As a result of his experiments, Dalton developed a theory in 1808 about the structure of matter that is called the **atomic theory.** In the atomic theory, Dalton stated the following:

- All matter is made of atoms (particles too small to see).
- Each element has its own kind of atom (atoms of the same element have the same mass; atoms of different elements have different masses).
- Compounds are created when atoms of different elements combine.
- Atoms cannot be created or destroyed.

Because he described atoms as indivisible spheres with constant composition throughout, this model became known as the "billiard ball" model of the atom.

Thomson's Model of the Atom

Dalton's theory of atomic structure was a significant breakthrough, but as more scientists armed with Dalton's theory studied the atom, some inconsistencies appeared.

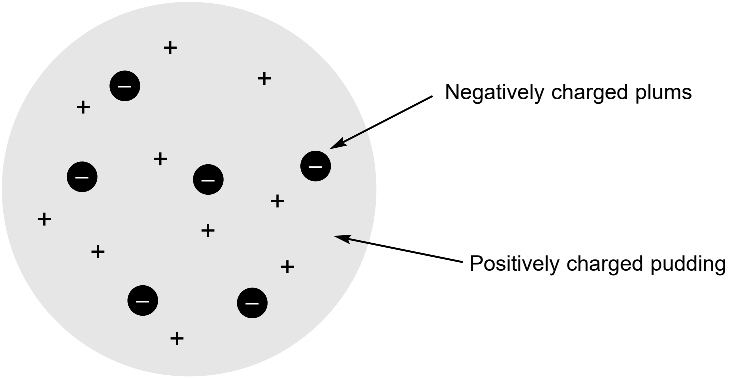
Scientists were aware that many elements demonstrated electrical properties. In 1897, J. J. Thomson, studying the effects of passing an electric charge through a gas, observed that the gas gave off negative electrical charges. Thomson knew the gas was neutral. Where did the negative charges come from? He concluded that the negative charges originated from gas molecules. This meant that smaller particles than the atom existed (i.e., the atom must be divisible).

Thomson's hypothesis about elements having smaller parts with an electric charge created a problem for scientists. How could the fact that neutral atoms were found to contain negative charge be explained? Atoms must also contain an equal number of positive charges. Therefore, atoms have an equal number of positive and negative particles. The combination of the two charges yielded a zero or neutral charge. Thomson, unable to find any positive particles in any atom, proposed a theory on the structure of the atom.

In his theory, Thomson proposed that an atom is a solid mass of positive charges with electrons placed throughout the mass, similar to plums in a pudding. As a result, Thomson's model (Figure 2.5) became known as the "plum pudding" model of the atom.

Thomson's model is important because it suggests there are smaller parts within each atom. Thomson is given credit for having discovered the subatomic particle that is called the **electron** (an advancement on Dalton's original view of the atom as a billiard ball, hard and indivisible). An electron is a negatively charged particle.

Figure 2.5 **Thomson's Model of the Atom**



A **subatomic** particle, a part of the atom, is smaller than the atom. The atom is made of various kinds of subatomic particles. The electron is recognized as a subatomic particle because it is a part of an atom. Thomson's model of the atom shows electrons as negatively charged plums in a positively charged pudding.

Thomson's model suggests the following:

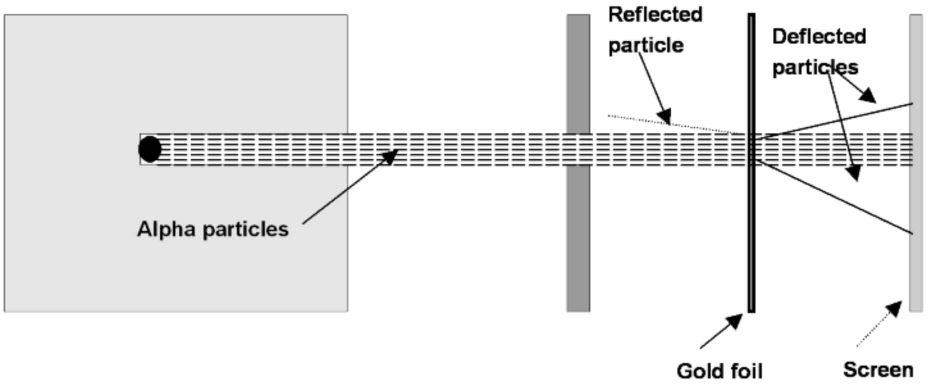
- Electrons have a small mass and a negative charge.
- Negative electrons are located in a positive sphere, so the resulting atom is electrically neutral.

Rutherford’s Model of the Atom

Ernest Rutherford set up an experiment that fired extremely small positively charged particles called **alpha particles** at a thin sheet of gold foil (gold can be hammered into extremely thin strips). Even though the foil is extremely thin, it is many atoms thick. Most of the positively charged “bullets” went straight through the foil without any change in direction. Rutherford realized that atoms, even heavy atoms of gold, must be far apart to allow almost all of the “bullets” to pass through. A few alpha particles were deflected slightly from their path. Rutherford discovered that only a few of the many bullets fired at the gold foil reflected almost straight back. After careful analysis of the deflection patterns, Rutherford concluded that an atom is made almost entirely of empty space with a dense, small, spherical mass in the centre. He named the dense sphere a **nucleus.** The size of the nucleus in relation to the rest of the atom is compared to the size of a marble in relation to a football stadium.

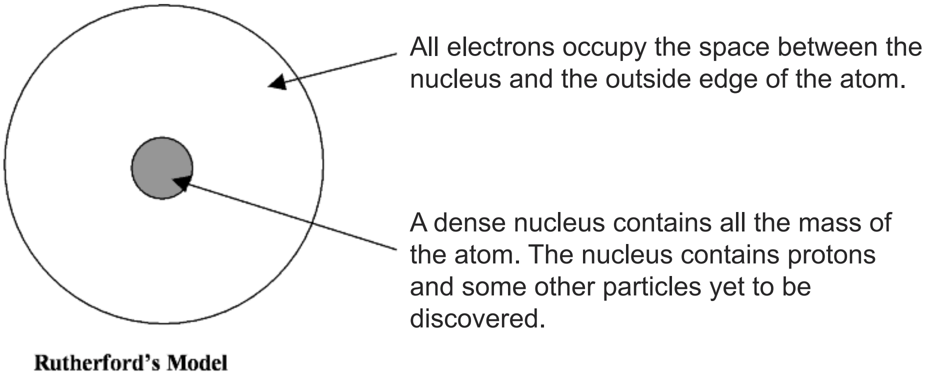
Figure 2.6

Relative Size of Nucleus



Rutherford’s theory was that all the positive charges are contained in the nucleus and the negative charges are in some way placed around the nucleus. While this theory improved on Thomson’s model, it did not properly explain the position of electrons in the atom. The positive charges that Rutherford discovered in the nucleus of the atom are called **protons**. Rutherford also suggested that the protons do not provide all the mass of the atom—the nucleus contained another type of particle.

Figure 2.7 **Rutherford`s Model of the Atom**



The model of the atom needed further refining. The next lesson shows how Bohr, Moseley, and Chadwick provided the refinements.

Rutherford's model increased an understanding of the atom by suggesting the following:

- The nucleus is a very small, dense, positively charged core of the atom.
- All of the atom's positively charged particles, called protons, are located in the nucleus of the atom.
- The nucleus is surrounded by mostly empty space.
- Rapidly moving, negatively charged electrons are scattered outside the nucleus around the atom's edge in what is referred to as the electron cloud.

Learning Activity 2.3: The Atom

1. State the four main points of Dalton’s atomic theory.
2. Describe how Thomson’s plum pudding model added to an understanding of the structure of the atom.
3. Describe the atom’s structure according to Rutherford’s hypothesis. Include a diagram with your description.

Check the answer key.

Summary

- Dalton’s atomic theory led the way for further exploration of the structure of the atom. His description of the structure of the atom remains essentially correct. Dalton’s atomic theory is summarized as
    - all matter is made of atoms
    - each element has its own kind of atom
    - compounds are formed when different elements link together to form a new material
    - atoms cannot be created or destroyed
- Thomson discovered that atoms have charges inside them. He hypothesized that there are equal numbers of positive and negative particles spread throughout the atom, similar to plums in a pudding.
- Rutherford fired minute particles, called alpha particles, at gold foil. He observed that most of the particles went right through the foil. Some of the particles deflected off the metal atoms. Sometimes an alpha particle would reflect back from the foil, indicating a direct hit. From this information, Rutherford hypothesized that atoms are mainly empty space with a hard, dense nucleus in the centre. He also hypothesized that electrons are in the space outside the nucleus and the positive charges are located in the nucleus.

LESSON 5: BOHR’S ATOMIC MODEL

Lesson Focus

After completing this lesson, you will be able to

- ☐ explain Bohr’s answer to the problem of electron position in the atom
- ☐ describe Bohr’s four hypotheses relating to the electron’s position in the atom
- ☐ describe the meaning of the orbit number
- ☐ describe the contributions Moseley and Chadwick made to the understanding of the structure of the atom
- ☐ compare and contrast Bohr’s model with Dalton’s model

Key Words

- orbit
- quantum theory
- proton
- atomic number
- neutron

Online Resources

The following website provides information about Bohr’s atomic model.

- HowStuffWorks, Inc.
  http://videos.howstuffworks.com/hsw/5787-niels-bohrs-atomic-model-video.htm

Bohr's Atomic Model

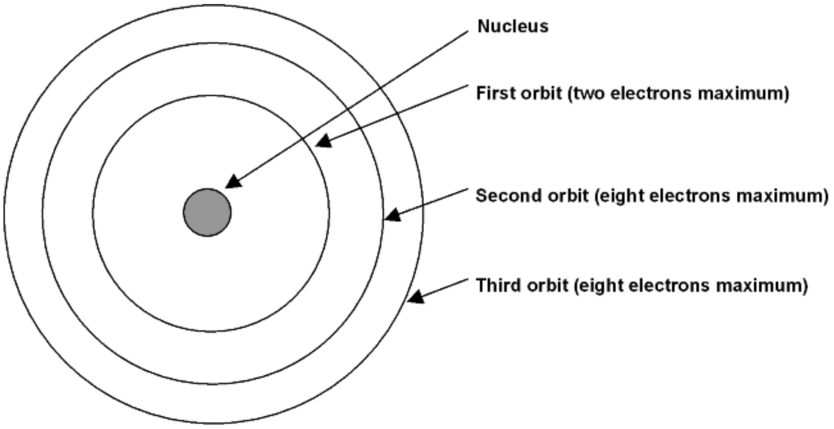
Rutherford's findings evolved from the experiments and theories of Dalton and Thompson. As a result, our understanding of atoms became clearer. Similarly, Niels Bohr used Rutherford's work to hypothesize new understandings about the model of an atom.

From Rutherford's experiments, scientists knew electrons occupy the space outside the nucleus of the atom. Niels Bohr's model of the atom proposed that electrons occupy special positions around the nucleus.

These special positions are called **orbits** or shells. In Bohr's theory, the orbits were circular. He suggested that electrons move in these orbits in much the same way that planets travel around the sun. Bohr discovered that the location of each orbit was a certain distance from the nucleus. Only a specific number of electrons populated each orbit.

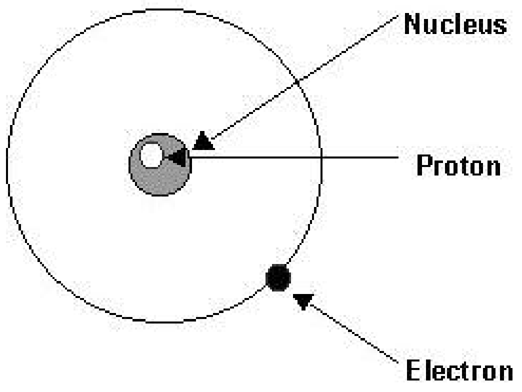
When electrons occupy the orbits, they begin at the closest orbit to the nucleus. The first orbit can contain a maximum of two electrons, and the second and third orbits allow a maximum of eight electrons each, as shown in Figure 2.8 below.

Figure 2.8 **Electron Arrangement**



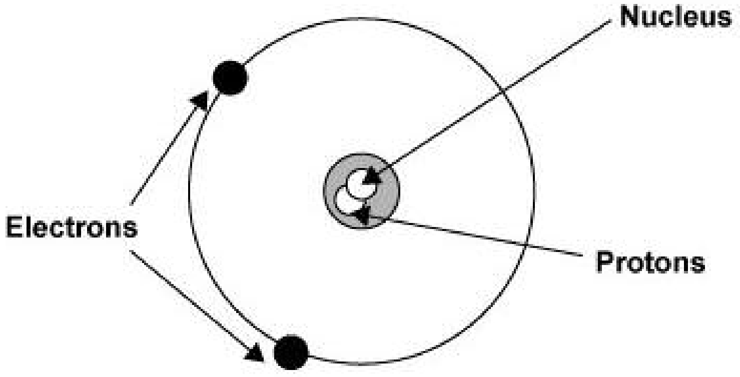
Bohr's model of the atom is often called the planetary model because it resembles the motion of planets around the Sun. Using this model, hydrogen, which has one proton in the nucleus and one electron, resembles a solar system with one planet travelling around the Sun (see Figure 2.9).

Figure 2.9 **Hydrogen**



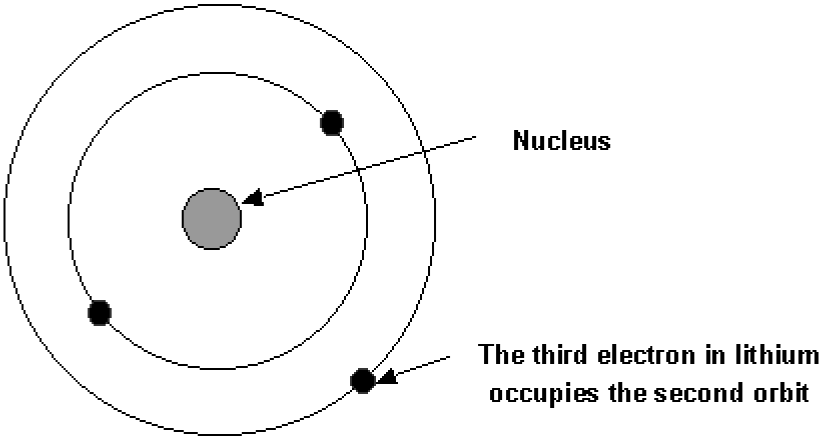
Hydrogen has one electron in orbit; helium, the next element, has two electrons (see Figure 2.10). The inner orbit cannot hold more than two electrons, so helium's inner orbit is considered full.

Figure 2.10 **Helium**



Lithium has three electrons. The first two electrons occupy the inner orbit and the third occupies the second orbit (see Figure 2.11).

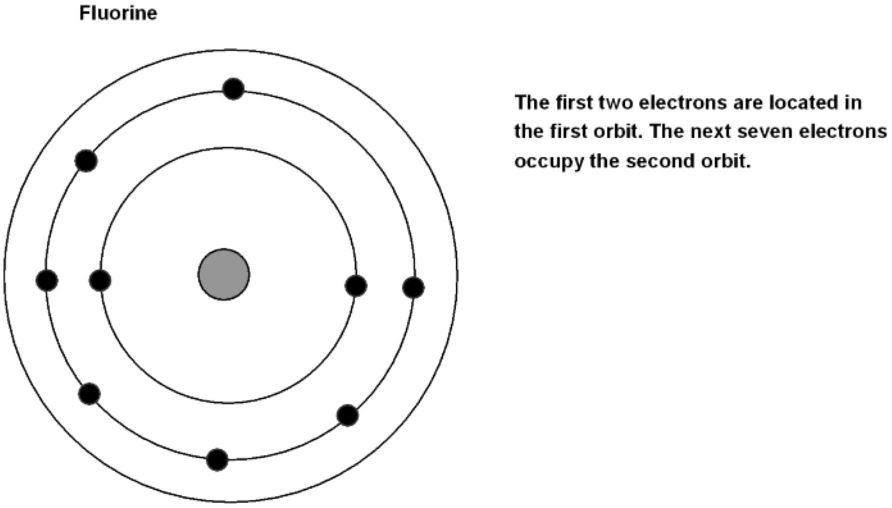
Figure 2.11 **Lithium**



The second orbit is eventually filled when it has eight electrons.

The Bohr model for fluorine is below (see Figure 2.12). Fluorine has nine electrons. Note how they populate the orbits around the nucleus.

Figure 2.12 **Fluorine**



Quantum Theory

Bohr's theory is called the quantum theory of the structure of the atom. In his theory, Bohr made four statements:

- Electrons travel around the nucleus of an atom in specific orbits.
- An electron must have the proper energy to occupy a given orbit.
- The orbit with the least energy is closest to the nucleus. Each orbit has a quantum number, n. In the first orbit, n = 1; in the second orbit, n = 2; and so on.
- Only a certain number of electrons can occupy any orbit. Electrons occupy the orbit with the lowest energy first and then occupy the next higher energy level orbit and so on, until each orbit is full.

The quantum theory proposed the following:

- According to the theory of wave mechanics, electrons do not move about the atom's nucleus in a definite path like planets around the sun.
- It is impossible to determine the exact location of an electron.
- The probable location of an electron is based on its energy.
- The quantum model of the atom shows how electrons move randomly in electron clouds called orbitals.

The Atomic Nucleus

As Bohr focused on the electrons, Henry Moseley worked on the structure of the nucleus of the atom. Moseley, using the same information as Bohr, discovered that the nucleus is filled with positive charges that are closely related to the atomic weight of the atom and its chemical activity. Moseley discovered an orderly increase in the positive charge of an atom as the atomic weight increased.

Ernest Rutherford suggested the name proton for the unit positive charge in the nucleus. Moseley called the number of **protons** (positively charged particles) in the nucleus of the atom its **atomic number.** The atomic number, as you will learn later, is significant in understanding the relationship between elements.

It is important to note that Thomson, Rutherford, Bohr, Moseley, and James Chadwick, among others, collaborated in their work. The late nineteenth and early twentieth centuries were golden years filled with excitement as these scientists made discoveries that opened up the secrets of the atom. However, as these scientists explored the atom, new questions arose.

Chadwick worked with Rutherford on his experiments to bombard metal foil. As they discovered the proton, they came to understand that protons could not account for the total mass of the nucleus. There had to be another particle, also located in the nucleus, which had no charge. It did not have a charge because the negative charge produced by the electrons was already balanced by the positive charges provided by the protons. The particle in the nucleus that Chadwick discovered is called a **neutron** (Rutherford suggested the name). The neutron has a mass approximately equal to the mass of a proton but has no electric charge.

Protons and neutrons are both located in the nucleus of the atom.

Learning Activity 2.4: Bohr's Atomic Model

1. How many electrons are able to occupy

   the first orbit? _______________

   the second orbit? _______________

   the third orbit? _______________

2. Describe how the Bohr model advanced understanding of the structure of the atom.

Check the answer key.

Summary

- Bohr's work on electrons resulted in the following statements about the position and behaviour of electrons.
    - Electrons can travel only in certain orbits around the nucleus.
    - An electron can only occupy an orbit when it has the proper energy.
    - Only a certain number of electrons can occupy any orbit.
- Henry Moseley discovered that for every electron there is a corresponding proton with a positive charge. He called the number of protons in an atom its atomic number.
- Chadwick detected the particles predicted by Rutherford and called them neutrons.

Notes

Assignment 2.1: Atomic Timeline (19 marks)

Over the years, researchers have refined our understanding of the atom’s structure. Your task is to create a poster that shows the different atomic models proposed by Dalton, Thomson, Rutherford, and Bohr.

- Your poster should be made on a paper that is at least 8.5" x 11" in size.
- It should provide an illustration of each of the four models. Label all important components.
- It should list the new discoveries made by each researcher, describing how they modified or added to the previous atomic model.

Content	Illustrations	Length and Style	Total Marks
8 marks	8 marks (2 marks per model)	3 marks	19 marks
■ lists the contributions that Dalton, Thomson, Rutherford, and Bohr made toward the development of today’s atomic model	■ includes labelled illustrations of the billiard ball model, plum pudding model, Rutherford model, and Bohr model	■ minimum 8.5" x 11" paper ■ clear title and subheadings ■ text is organized into sections ■ uses colour and pictures	
/8	**/8**	**/3**	**/19**

Notes

LESSON 6: A HISTORY OF THE ELEMENTS

Lesson Focus

After completing this lesson, you will be able to

- ☐ explain why scientists accepted that there are more elements than those proposed by Empedocles
- ☐ demonstrate an understanding of the origins of the names of elements
- ☐ use the rules for assigning symbols to elements
- ☐ name and write the symbols for the first 18 elements as well as for K, Ca, Fe, Ni, Cu, Zn, I, Ag, Sn, Au, W, Hg, Pb, U

Key Words

- inert

Online Resources

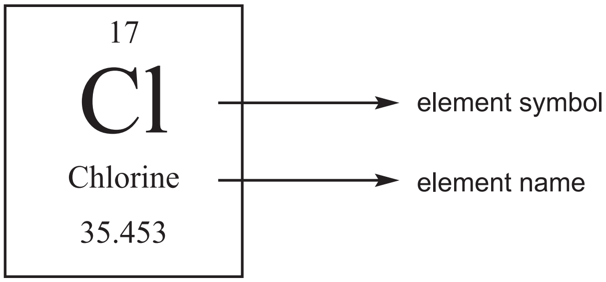
The following website provides a periodic table listing all the elements and their properties.

- Mark Winter, University of Sheffield and Web Elements Ltd. UK
  www.webelements.com/webelements.html

On the next page you will find a copy of the periodic table. You will need to use the periodic table throughout the rest of your study of Module 2. You may want to flag this page so that you can find it easily.

For Lesson 6, you need to understand only the element name and symbol (See Figure 2.13). There will be further explanation about the other information included on the periodic table in later lessons.

Figure 2.13 **Periodic Table Information**



Names for New Elements

Once early scientists began discovering the existence of a few elements, many more elements were discovered. New techniques for isolating elements were used with great success. All these new elements needed names and symbols.

Note:

- Chemical symbols are shorthand methods for identifying any element. The symbol usually consists of the first letter in the name of the element, and is capitalized (e.g., C is the symbol for carbon).
- If two elements have the same first letter, the symbols consist of two letters with the first letter capitalized, and the second letter lower case (e.g., calcium is Ca and cobalt Co).
- Some symbols originated from a Greek or Latin name, in which case the symbol for the element does not relate to the English name (e.g., Na is the symbol for sodium).

A partial list of elements follows. The name of the element, along with its symbol, is shown on the first line, followed by a brief description of the origin of the name and some basic information about the element.

Hydrogen H

Greek—*Hydro* (water) *Genes* (forming)

Henry Cavendish (in 1766) prepared hydrogen long before it became known as an element. Lavoisier named the element. Hydrogen is the most abundant element in the universe, making up 90 percent of all atoms and 75 percent of all mass. The name *hydrogen* means water forming, which resulted from Lavoisier's experiment with hydrogen burning in oxygen.

Helium He

Greek—*Helios* (Sun)

Hans Janssen first observed helium during a solar eclipse in 1895. Janssen used a spectroscope to analyze the light from the sun and detected a new element. The Greek name for sun was a natural choice for a name. Helium is the second most abundant element in the universe. Most of the helium produced in Canada and the United States comes from wells. Helium is used for filling balloons because it is not flammable and it is lighter than air. Helium is an important part of rocketry as it is used to pressurize liquid fuel in rockets.

Lithium Li

Greek—*Lithos* (stone)

Lithium is the lightest of the metals and could easily float on water, except that it reacts with water. Lithium is often found in different igneous rocks.

Beryllium Be

Greek—*Berryllos* (sweet)

Beryllium, discovered in 1798 in an emerald called Beryl, has many desirable characteristics. It is used to make different alloys. Beryllium is toxic and should never be tasted for its sweetness or handled by anyone without training.

Boron B

Persian—*Burah*

Boron compounds have been known for thousands of years. Sir Humphry Davy first isolated the element in 1808. Boron gives off a green colour in flares. Boron forms boric acid which is used as a mild antiseptic.

Carbon C

Latin—*Carbo* (charcoal)

Carbon is a common element found in nature. Carbon can exist as graphite, one of the softest materials known, and diamond, one of the hardest materials known.

Nitrogen N

Latin—*Nitrum* (soda) *Genes* (forming)

Daniel Rutherford discovered nitrogen in 1772. Nitrogen makes up about 78 percent of the earth’s atmosphere.

Oxygen O

Greek—*Oxys* (sharp, acid) *Genes* (forming)

Oxygen forms 21 percent of the earth’s atmosphere. Two-thirds of the human body is oxygen. Oxygen is essential to combustion.

Fluorine F

Latin—*Fluere* (flux)

In 1529, Georgius Agricola used fluorspar as a flux in the processing of metals. Hydrofluoric acid is used to etch glass, and fluorine is dissolved in water supplies to prevent tooth decay.

Neon Ne

Greek—*Neos* (new)

Neon is an **inert** element, meaning it does not react with any other substance. It is used in making neon advertising signs and gas lasers.

Sodium Na

Latin—*Natrium*

Davy first isolated sodium in 1807. The most common compound of sodium is sodium chloride, or table salt. Pure sodium is a soft, shiny metal that reacts violently with water.

Magnesium Mg

Magnesia, a district where it was mined

Magnesium was first identified as an element in 1755. Finely divided magnesium easily ignites in air to produce a brilliant white light. In the early years of photography, camera operators used this element to make flashes.

Aluminum Al

Latin—*Alumen*

Friedrich Wöhler isolated pure aluminum in 1827. Aluminum is light, ductile (can be drawn into wire), and corrosion resistant. Aluminum cars, for example, resist rusting.

Silicon Si

Latin—*Silicis* (flint)

Baron Jöns Jacob Berzelius produced pure silicon in 1824. Silicon is used in many different compounds to form some of our most important materials. These include glass, silicon carbides in grinders, solid-state electronics materials such as transistors, and the substrate in chip technology.

Phosphorous P

Greek—*Phosporos* (light bearing)

Phosphorous was discovered in 1669. Phosphorous burns spontaneously in air. It is very poisonous. Phosphate compounds are important fertilizers.

Sulfur S

Latin—*Sulphurium*
Sulfur is referred to in the Bible, book of Genesis, as brimstone. One of the most important compounds of sulfur is sulfuric acid.

Chlorine Cl

Greek—*Chloros* (greenish-yellow)
Davy named chlorine in 1810. Chlorine is a greenish-yellow gas. Chlorine is used worldwide to purify drinking water, and can be used to bleach clothes.

Argon Ar

Greek—*Argos* (inactive)
Lord John Rayleigh and Sir William Ramsay discovered argon in 1894. Welders use argon as a gas shield.

Potassium K

English—*Potash*
Davy discovered potassium in 1807. Potash is a potassium compound that is in great demand as a fertilizer.

Calcium Ca

Latin—*Calx* (lime)
The Romans prepared lime (calcium oxide) from calcium in the first century. Calcium is one of the main components of cement.

Iron Fe

Latin—*Ferrum*
Iron is the basic material in steel. Different amounts of carbon and other trace elements are responsible for the many types of steel.

Nickel Ni

German—*Nickel* (Satan)
Nickel is used to produce stainless steel.

Copper Cu

Latin—*Cuprum* (from the island of Cyprus)
The discovery of copper goes back to prehistoric times. Copper is used as a conductor in electrical applications. Copper is also part of an alloy used in most coins.

Zinc Zn

Zinc is an essential element in the growth of animals. Zinc has many applications in the production of materials such as paint, cosmetics, and plastics.

Periodic Table

Transition Elements

IA	IIA	IIA	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	IIIA
Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																1 **H** Hydrogen 1.0	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krpton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.5	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.7	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	71 **Lu** Lutetium 175.0	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	103 **Lr** Lawrencium (257)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (264)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 **Uun** Ununnilium (268)	111 **Uuu** Unununium (272)	112 **Cp** Copernicium (277)		114 **Uuq** Ununquadium (285)		116 **Uuh** Ununhexium (268)		118 **Uuo** Ununoctium (293)

Larthanide Series	57 **La** Lanthanum 138.9	58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4	63 **Eu** Europium 152.0	64 **Gd** Gadolinium 157.2	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0
Actinide Series	89 **Ac** Actinium (227)	90 **Th** Thorium 232.0	91 **Pa** Protactinium (231)	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (254)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (256)	102 **No** Nobelium (259)

Silver Ag

Latin—*Argentum*
Silver has been known since ancient times. It is an important part of photography. Silver salts are used to form the photographic image.

Mercury Hg

Latin—*Hydrargyrum* (“liquid silver”)
Named after the planet Mercury. Mercury is the only common element that is a liquid at room temperature.

Tin Sn

Latin—*Stannum*
Tin has many industrial uses, but is best known as a coating on “tin” cans which are really tin-coated steel cans.

Lead Pb

Latin—*Plumbum*
Lead has been used for thousands of years. The Romans used lead in pipes and sealants in their water systems (the word *plumber* was derived from the Roman word for lead).

Iodine I

Greek—*Lodes* (violet)
Iodine is a bluish-black solid. Lack of iodine in the diet is responsible for a condition known as goitre. This element was once used as an antiseptic.

Uranium U

Named after the planet Uranus. Uranium is the heaviest of the naturally occurring elements and is radioactive. Uranium is a fuel for nuclear reactors.

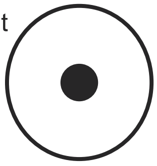
Tungsten W

From the Swedish words *tung sten* meaning “heavy stone” (the origin of the symbol W is “wolfram,” named after the tungsten mineral wolframite).

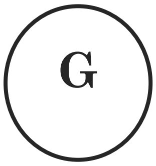
Gold Au

Latin—*Aurum*

The alchemist symbol for gold was



Dalton’s symbol for gold was



Gold was known as a noble metal since it would not react with chemicals. Gold will remain underwater and not rust or corrode from salt. Gold is not reactive with acids. Gold is also very ductile (can be drawn into wire) and malleable (can be hammered into thin sheets). Since ancient times, gold has been used to represent wealth.

The short list shown below contains the elements described in the previous pages. The element is shown in the left column and the corresponding symbol is located in the right column.

Element	**Symbol**	**Element**	**Symbol**
Hydrogen	H	Chlorine	Cl
Helium	He	Argon	Ar
Lithium	Li	Potassium	K*
Beryllium	Be	Calcium	Ca
Boron	B	Iron	Fe*
Carbon	C	Nickel	Ni
Nitrogen	N	Copper	Cu*
Oxygen	O	Zinc	Zn
Fluorine	F	Silver	Ag*
Neon	Ne	Tin	Sn*
Sodium	Na*	Iodine	I
Magnesium	Mg	Tungsten (Wolfram)	W*
Aluminum	Al	Gold	Au*
Silicon	Si	Mercury	Hg*
Phosphorous	P	Lead	Pb*
Sulfur	S	Uranium	U

* Elements with an asterisk do not obey the rules for determining symbols from element names.

Learning Activity 2.5: Table of Elements and Symbols

1. Fill in the symbols for the elements in the table below.

Element	**Symbol**	**Element**	**Symbol**
Aluminum		Iodine	
Oxygen		Helium	
Lithium		Neon	
Chlorine		Calcium	
Uranium		Mercury	
Nickel		Carbon	
Lead		Copper	
Argon		Phosphorous	
Sulfur		Hydrogen	
Potassium		Sodium	
Tin		Beryllium	
Gold		Tungsten (Wolfram)	
Silver		Magnesium	
Boron		Nitrogen	
Zinc		Iron	
Fluorine		Silicon	

Use the table on the previous page or your periodic table to check your answers.

continued

Learning Activity 2.5 (continued)

2. Write the name of the element beside the appropriate symbol in the table below.

Element	Symbol	Element	Symbol
	Na*		B
	He		P
	Ag*		O
	I		Be
	Cl		Si
	Cu*		Ne
	N		Au*
	K*		F
	Zn		S
	Ni		Sn*
	H		Ca
	W*		Mg
	Hg*		C
	Fe*		Al
	Ar		Pb*
	U		Li

*Elements with an asterisk do not follow the rules for determining symbols from element names.
Use the table on page 48 or your periodic table to check your answers.

continued

Learning Activity 2.5 (continued)

3. Respond to each statement by writing the symbol of the element best matching the clue.

Statement	Element Symbol
1. The element used in weather balloons.	
2. The element found in cheaper light bulbs.	
3. The element used in water purification.	
4. The element used in photographic film.	
5. The element used in expensive dental fillings.	
6. The only common element that is a liquid at room temperature.	
7. The element used as sealants in water pipes.	
8. The element most used as an electrical conductor.	
9. The element once used as an antiseptic.	
10. The element used in the production of fertilizers.	
11. The metal element used in electroplating.	
12. The element used in pencil leads (not lead).	
13. The element used to absorb heat in spacecrafts.	
14. The element used in modern batteries.	
15. The gas element most used in scuba diving air tanks.	
16. The element used in the making of steel.	
17. The element used as a fuel component in nuclear reactors.	

Check the answer key.

Notes

LESSON 7: MODERN ATOMIC THEORY

Lesson Focus

After completing this lesson, you will be able to

- ☐ use the modern atomic theory to describe the meaning of the terms atomic number, mass number, and atomic mass
- ☐ predict the number of protons, electrons, and neutrons knowing the atomic number and the mass number of an atom
- ☐ state the charge, location, and mass of the subatomic particles

Key Words

- atomic mass unit (u or amu)
- nucleons
- atomic number
- atomic mass
- mass number

Atomic Theory—Review

Dalton's theory for the structure of the atom stands fundamentally correct today. His understanding that atoms cannot be broken down, however, has been proven incorrect. Atoms can be broken down into subatomic particles. The three main subatomic particles are protons, neutrons, and electrons. In the previous lesson, you discovered that Thomson, Rutherford, Bohr, Moseley, and Chadwick were largely responsible for developing an understanding of the atom's structure.

The Bohr model of the atom suggested that electrons travel in a circular orbit in well-defined paths. Scientists have done experiments to show that this is not the path electrons actually travel. Electron location and movement are more complicated than Bohr thought. The planetary model of the atom is used, however, because it is easier to understand and is adequate for an introductory course in chemistry.

The modern atomic theory states that an atom consists of the following:

- Protons located in the nucleus of the cell. Protons have a positive charge and have a mass of one **atomic mass unit** (**u or amu**). An atomic mass unit is defined as 1/12th the mass of a carbon atom, which means that 1**u** is equal to the mass of a proton.
- Neutrons are also located in the nucleus of the atom. Neutrons have no electrical charge and have a mass of approximately 1**u**. The protons and neutrons together are called **nucleons**.
- Electrons are located around the nucleus in less defined orbits than Bohr had predicted. Electrons have a single negative electrical charge but their mass is considered to be zero since it is so small.

Learning Activity 2.6: Subatomic Particles

Fill in the table below.

	Charge	Location	Mass	Discovered by
Protons				
Electrons				
Neutrons				

Check the answer key.

All atoms are made of protons, neutrons, and electrons (i.e., a proton in a carbon atom is the same as a proton in an oxygen atom). The same is true for electrons and neutrons. What determines the difference between atoms of different elements if they are all made of the same subatomic materials? The answer is that atoms of different elements have different numbers of protons in the nucleus and of electrons around the nucleus.

Atomic Number

Henry Moseley originally developed the concept of **atomic number**. The atomic number is determined by the number of protons in the nucleus. The atomic number is special because it can be used to identify any known element. It is easy to identify copper because it has an atomic number of 29. Carbon has an atomic number of 6, oxygen has an atomic number of 8, and so on. Check your periodic table to see if you can locate the atomic numbers of copper, carbon, and oxygen. See Figure 2.14 on page 54.

Learning Activity 2.7: Atomic Numbers

Place the atomic symbol in the parentheses following the names in the table below. Fill in the blanks with the values for the atomic number and number of protons. Use your periodic table to help you complete this task.

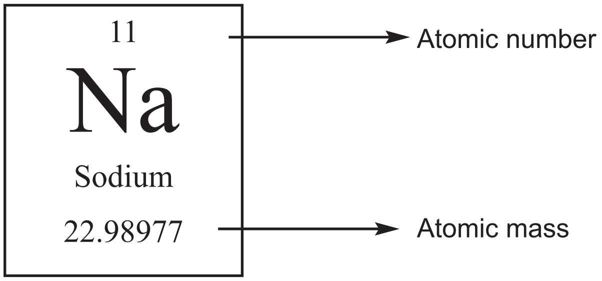
	Iron ( )	Krypton ( )	Uranium ( )	Sodium ( )
Atomic Number				
Number of Protons				

Check the answer key.

Atomic Mass

Atomic mass is the average mass of an atom or the average total mass of the protons, neutrons, and electrons of an atom. The units for atomic mass are atomic mass units (or amu).

Figure 2.14 **Labelling in the Periodic Table**



Mass Number

All atoms have a mass number. The mass number is equal to the number of protons plus the number of neutrons. You can determine the mass number of an atom simply by rounding its atomic mass to the nearest whole number.

For example:

The atomic mass of sodium is 22.98977 amu.

The mass number of sodium must then be 23 (no units).

The atomic number of sodium is 11, which means there are 11 protons and 11 electrons.

This must mean that there are (23 – 11) 12 neutrons.

Mass Number = atomic number (number of protons) + number of neutrons

You can solve for the atomic number or the number of neutrons by modifying the formula shown above:

Atomic Number (number of protons) = mass number – number of neutrons

Number of neutrons = mass number – atomic number (number of protons)

Learning Activity 2.8: Mass Numbers

Use your understanding of mass number and the periodic table to calculate the values for the blank spaces in the table below. Place the proper symbol for the elements in the parentheses.

	Lithium ( )	Chlorine ( )	Copper ( )	Silver ( )
Number of Protons				
Number of Neutrons				
Mass Number				

Check the answer key.

Determining the Number of Subatomic Particles

Number of protons

The number of protons is equal to the atomic number.

Number of electrons

All atoms are electrically neutral, i.e., they have equal numbers of protons and electrons. In any atom the number of electrons is equal to the atomic number.

Number of neutrons

The mass number is always equal to the number of protons plus the number of neutrons. The number of neutrons would then be equal to the mass number minus the atomic number.

Number of neutrons = mass number – atomic number

Table Summarizing Calculation of Number of Subatomic Particles

Number of protons	↔	Atomic number
Number of neutrons	↔	Mass number – Atomic number
Number of electrons	↔	Atomic number

Summary

- An atom is made of protons, neutrons, and electrons.
- Electrons travel in defined orbits or shells around the nucleus.
- Atomic number is equal to the number of protons. Atomic number identifies the atom.
- Mass number is equal to the number of protons plus the number of neutrons.

LESSON 8: BOHR ATOMS

Lesson Focus

After completing this lesson, you will be able to

☐ draw Bohr models for the first 18 elements

Key Words

- valence shell

You will draw some Bohr atoms in this lesson. Before beginning that task, however, we will review what you have learned about atomic structure up to this point.

An atom consists of a dense nucleus surrounded by electrons moving in space.

Nucleus

- A nucleus is made of protons and neutrons.
  - Protons and neutrons both have a mass of 1**u.**
  - Protons have a positive charge (+1); neutrons have no charge.
  - The total mass of the atom is equal to the mass of the protons and neutrons in the nucleus.
- If an atom were the size of a football stadium, the nucleus would be the size of a football.
- The atomic number of an atom is equal to the number of protons in the nucleus.
- The mass number is equal to the sum of the number of protons and neutrons. The mass number has no units.

Electrons

- Electrons travel around the nucleus in specific paths called shells.
  - Shells exist whether there is an electron in them or not.

- Electrons occupy certain shells depending on the atom. For example, hydrogen has a single electron in the first shell; sodium has two in the first shell, eight in the second shell, and one in the third shell.
- An atom can have a maximum of two electrons occupying the first shell, eight in the second shell, and eight in the third shell. We will not study the structure of atoms with more than three levels of shells. Each shell must be filled before electrons occupy the next one.
- We will use the term *outermost orbit* or *outer orbit* to refer to the outermost orbit that is occupied, even if there are orbits/shells further out that are unoccupied. This is often referred to as the **valence shell.**
- Electrons are so light they are considered to have zero mass.
- Electrons have a negative electric charge (–1).

Learning Activity 2.9: The Bohr Model

1. Draw Bohr atoms for the first eight elements.
2. Use the atoms you have drawn and arrange the names of the atoms in the table below according to the number of electrons in the outer shell.

One Electron in Shell 1	
Two Electrons in Shell 1	
One Electron in Shell 2	
Two Electrons in Shell 2	
Three Electrons in Shell 2	
Four Electrons in Shell 2	
Five Electrons in Shell 2	
Six Electrons in Shell 2	

Check the answer key.

Assignment 2.2: Subatomic Particles and the Bohr Model (30 marks)

1. Draw Bohr models for the following elements: *(3 marks)*

   Hydrogen Magnesium Fluorine

2. An atom has 10 protons in its nucleus.
   a. Draw its Bohr model. *(1 mark)*

   b. What atom is this? *(1 mark)* ______________________________

3. At atom has a mass number of 31.
   a. Draw its Bohr model. *(1 mark)*

   b. What atom is this? *(1 mark)* ______________________________

4. Use your understanding about the subatomic particles and the periodic table to complete the following chart. (0.5 mark each = 17 marks)

Element	Atomic Number	Mass Number	Number of Protons	Number of Electrons	Number of Neutrons
Carbon					
	53				
				26	
			19		
	80				
		14			
			16		16

5. An atom of gold has an atomic number of 79 and a mass number of 197. *(4 marks)*

a. How many protons are there in one atom of gold? ____________________

b. How many electrons are there in one atom of gold? __________________

c. How many neutrons are there on one atom of gold? _________________

d. How many protons are there in 10 atoms of gold? ____________________

6. Define and give an example of the following: (*2 marks each*)

a. Atomic number ____

____

____

____

b. Mass number ____

____

____

____

c. Atomic Mass ____

____

____

____

Notes

LESSON 9: MENDELEEV'S PERIODIC TABLE

Lesson Focus

After completing this lesson, you will be able to

☐ demonstrate how Dmitri Mendeleev's periodic table is a summary of the structure and properties of the known elements
☐ explain why Mendeleev reversed iodine and tellurium
☐ explain why Mendeleev left gaps in his periodic table
☐ define Mendeleev's periodic law
☐ explain how Mendeleev predicted the existence and properties of undiscovered elements
☐ arrange elements in a periodic order given their atomic masses and properties
☐ explain how Mendeleev's work benefits chemists

Key Words

- periodicity
- periodic law
- periodic table

In the previous lessons, you have been studying the discovery and naming of atoms and elements. These discoveries were made based on experimentation, and scientists needed an organized method to record their data and information about each of these elements.

Dmitri Mendeleev's New Way to Classify Elements

By the middle of the nineteenth century, scientists had discovered approximately 63 elements. Scientists arranged them alphabetically because there was no system for classifying elements. Unfortunately, an alphabetic arrangement of elements was an awkward way of grouping them (under this system, aluminum, a metal, would be grouped with argon, an inert gas—a completely different kind of element).

Scientists needed a way of classifying elements so that elements with similar properties would be placed together. This grouping system would increase the ability of scientists to predict the properties of some elements without having to analyze them.

Dmitri Mendeleev, a Russian scientist and professor, placed characteristic properties of elements on pieces of paper and arranged them in many different ways. He discovered a certain pattern or repetition of properties.

This discovery of repetition of properties or **periodicity** was an important outcome of Mendeleev's work. Mendeleev used the periodicity of properties to create a **periodic table.** This table summarized the structure and properties of the elements. The **periodic law** states the following: If elements are arranged according to their atomic mass, a pattern can be seen in which similar characteristic properties occur regularly.

Mendeleev's table of periodicity is shown on the next page (see Figure 2.16). As you look at the table, notice that atomic masses were used to position the elements. In almost every case, the atomic mass values increase across the rows. Can you find an exception? Name the element that has a decreasing atomic mass to the right of it in a row.

Figure 2.15 ***Arranging Elements according to Atomic Mass***

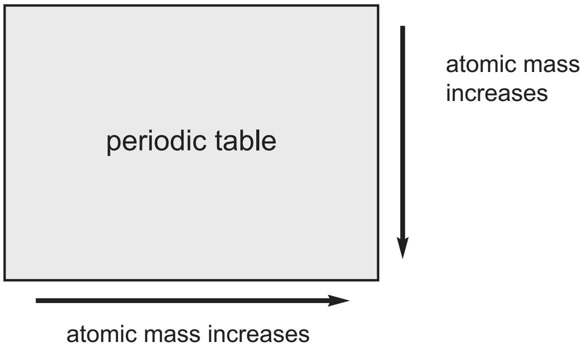
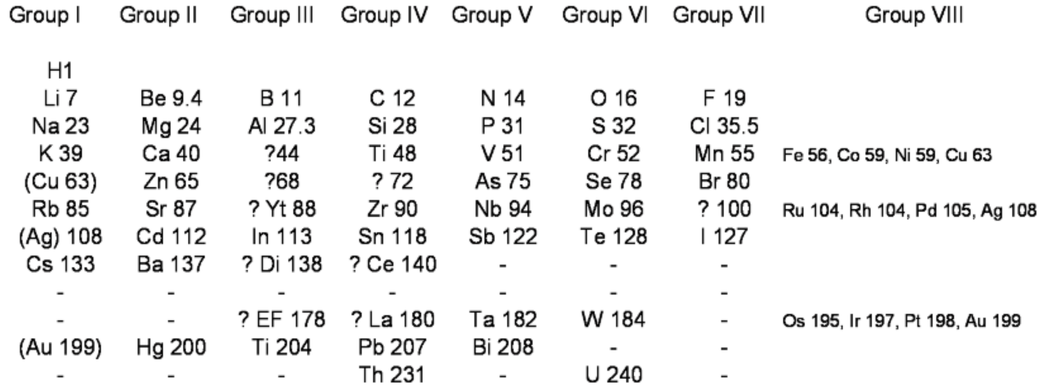


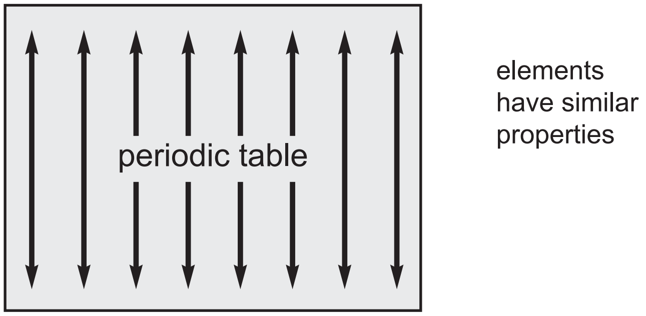
Figure 2.16 **Mendeleev's Periodic Table**



Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
H1							
Li 7	Be 9.4	B 11	C 12	N 14	O 16	F 19	
Na 23	Mg 24	Al 27.3	Si 28	P 31	S 32	Cl 35.5	
K 39	Ca 40	?44	Ti 48	V 51	Cr 52	Mn 55	Fe 56, Co 59, Ni 59, Cu 63
(Cu 63)	Zn 65	?68	? 72	As 75	Se 78	Br 80	
Rb 85	Sr 87	? Yt 88	Zr 90	Nb 94	Mo 96	? 100	Ru 104, Rh 104, Pd 105, Ag 108
(Ag) 108	Cd 112	In 113	Sn 118	Sb 122	Te 128	I 127	
Cs 133	Ba 137	? Di 138	? Ce 140	-	-	-	
-	-	-	-	-	-	-	
-	-	? EF 178	? La 180	Ta 182	W 184	-	Os 195, Ir 197, Pt 198, Au 199
(Au 199)	Hg 200	Ti 204	Pb 207	Bi 208	-	-	
-	-	-	Th 231	-	U 240	-	

Closely examine Mendeleev's Periodic table. Each of the vertical groups contains elements with similar characteristic properties.

Figure 2.17 ***Arranging Elements according to Properties***



As Mendeleev placed the elements in order of their atomic masses, he noticed that the properties of some elements did not seem to fit with the other elements in the same column. As a result, he decided to leave a gap in the row when this happened. He assumed that there were elements that had not yet been discovered that would fit into the gaps he left.

Mendeleev predicted the properties of the elements he left a gap for in his periodic table. He used properties of the other elements in the same column to make these predictions.

The problem with Mendeleev's periodic table, however, occurred when atoms were organized on the basis of atomic mass only.

Properties of the elements did not always match when atomic mass was used. Mendeleev had to use matching properties as the primary rule for arranging elements in the periodic table. By using matching properties, Mendeleev was able to place iodine and tellurium in their proper places.

Henry Moseley helped develop a solution to Mendeleev's atomic mass problem. Moseley's work led to a better understanding of the nucleus of the atom and from his work the concept of atomic number arose. Elements in the present-day periodic table are arranged according to atomic number (e.g., argon [181] precedes potassium [191]). This arrangement eliminated the inconsistencies found in Mendeleev's table.

Learning Activity 2.10: Mendeleev's Periodic Table

1. Use Mendeleev's table (shown in your lesson) to find an element that is out of position on the basis of atomic mass because similar properties were more important.
2. a. How were elements in Mendeleev's periodic table arranged?
   b. What is Mendeleev's periodic law?
3. Explain why Mendeleev included blanks in his periodic table. How did these blank spaces strengthen the belief in his method of organizing the elements?
4. Why was Mendeleev able to predict the properties of the elements that belonged in the blanks in his table?

Check the answer key.

Summary

- Mendeleev transformed an earlier understanding about the classification of elements into a grand plan called the periodic table.
- Mendeleev discovered (with a few exceptions) that arranging elements in order of increasing atomic mass across rows and similar characteristic properties down columns would result in elements obeying the periodic law (i.e., they repeated their characteristic properties regularly).
- Mendeleev believed that missing elements had yet to be discovered. Mendeleev left these spots open, predicted their characteristic properties accurately, and expected that these elements were yet to be discovered.
- The exceptions to the increasing atomic mass rule were iodine and tellurium. Mendeleev handled the problem by placing the element in the periodic table according to characteristic properties and ignored the atomic mass.
- Moseley solved Mendeleev’s problem by arranging elements in order of increasing atomic number.

Notes

LESSON 10: MODERN PERIODIC TABLE

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe the main difference between Mendeleev's periodic table and a modern periodic table
- ☐ describe why the modern periodic table does not have the same conflicts as Mendeleev's periodic table
- ☐ describe the terms used for rows and columns in a periodic table
- ☐ identify properties of alkali metals, alkaline-earth metals, halogens, chalcogens, and noble gases
- ☐ compare and contrast the alkali metals, alkaline-earth metals, halogens, chalcogens, and the noble gases (specifically their combining capacity and reactivity)
- ☐ predict the properties of an element based on its position in a periodic table

Key Words

- group or family
- alkali metals
- alkaline-earth metals
- chalcogen
- halogen
- noble gas
- hydrogen
- periods

Online Resources

The following website provides information on the modern periodic table.

- Mark Winter, University of Sheffield and WebElements Ltd., UK. http://webelements.com/

By clicking on an element, a full description of the element is provided.

A Modern Periodic Table

Mendeleev's periodic table was a significant advancement in the attempt to classify elements. Using his table, Mendeleev predicted the properties of chemicals before they were discovered.

Some flaws, however, occurred in Mendeleev's periodic table. As he used increasing atomic mass to place elements, Mendeleev discovered that tellurium and iodine were reversed in terms of their properties. Later, as cobalt and nickel were discovered, they also showed the same reversal and, later still, argon and potassium were found to be reversed. Mendeleev would use the properties of an element as the primary factor in positioning the elements in the periodic table and overcome the problem. Why did the problem develop in the first place?

Henry Moseley, while doing some experiments with X-rays, discovered that the nucleus of an atom had a specific positive charge. The positive charge was a unique value for a given element. As a result, any element could be identified by its positive nuclear charge. The positive charge was given the name atomic number. When elements were arranged according to their atomic numbers, the periodic law was demonstrated and the difficulty with Mendeleev's table disappeared.

As a result, a new periodic law was established. Today's periodic law states that the properties of elements are a periodic function of their atomic numbers (that is, the properties of elements can be predicted based on their atomic numbers).

Design of the Periodic Table

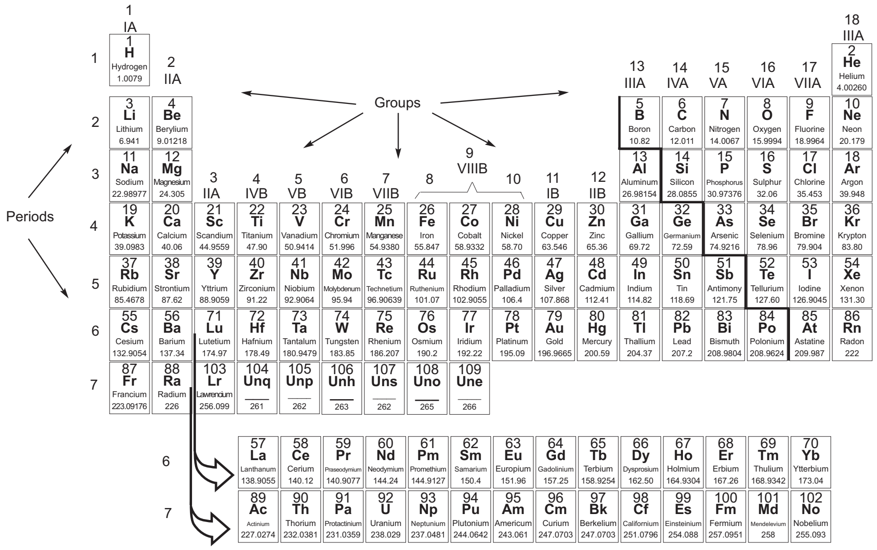
The periodic table is an important tool for chemists. It quickly determines some key facts about an element. You have been using a modern periodic table to help you with your calculations of protons, neutrons, and electrons.

The basic information with regard to the structure of an atom is quickly established with the periodic table.

Columns in the Periodic Table

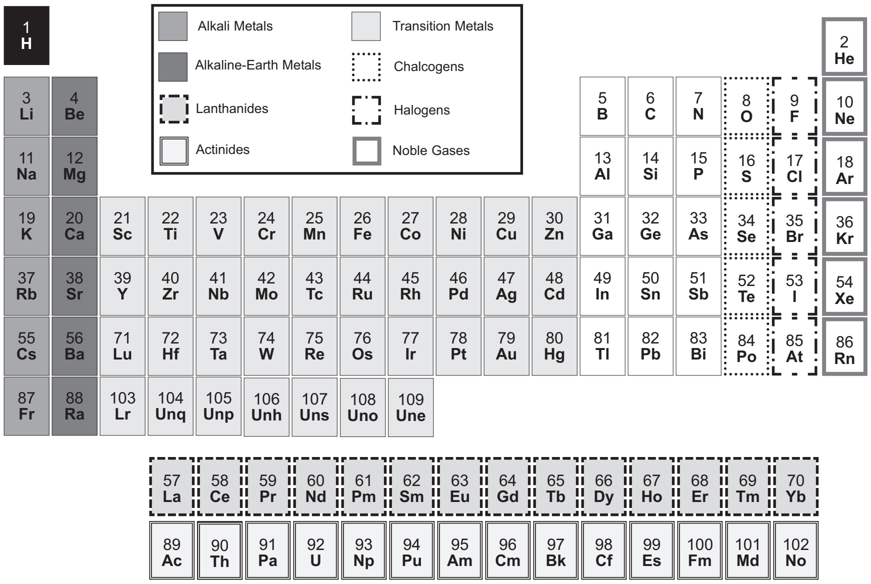
The periodic table in Figure 2.18 arranges the elements in columns. A single column is called a **group** or **family.** A family contains elements that have similar but not identical properties. There are two numbering systems for the columns (see Figure 2.18).

Figure 2.18 **Organization of the Periodic Table**



The families to review in some detail are called the alkali metals, alkaline-earth metals, chalcogens, halogens, and noble gases (see Figure 2.19).

Figure 2.19 ***Chemical Families of Elements***



Alkali Metals

The **alkali metal** family occupies the first column in the periodic table. It includes lithium (Li), sodium (Na), potassium (K), et cetera. If you examine the Bohr model of each of these elements, they all have one electron in their outer orbit. These metals are the most reactive metals in the periodic table because of the single electron in the outer orbit.

In their natural state, alkali metals are always found combined with other substances because of their reactivity. The most common element in the family is sodium, which is found all over the earth in compounds like salt (sodium chloride). All alkali metals are solid at room temperature.

Alkaline-Earth Metals

The **alkaline-earth metal** family is located in the second column of the periodic table. Alkaline-earth metals are less reactive than the alkali metal family. Their lesser activity arises from having two electrons in the outer orbit. Beryllium (Be) is the first member of the family followed by magnesium (Mg), calcium (Ca), strontium (St), barium (Ba), and radium (Ra). All alkaline-earth metals are solid at room temperature.

Halogens

The halogen family is the 17th family in the periodic table and includes fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At). Halogens such as fluorine and chlorine react with one atom of hydrogen to form HF and HCl respectively. The halogens are one electron short of filling their outermost orbit.

The halogens are the most reactive non-metals in the periodic table. In their natural state, the highly reactive halogens are found combined with another element. Chlorine compounds are the most common found on Earth.

Chalcogens

The **chalcogen** family is located in the 16th column of the periodic table. Members of the chalcogen family are slightly less reactive than these of the halogen family since they require two electrons to complete their outer orbit. The first member of the chalcogen family is oxygen (O), followed by sulphur (S), selenium (Se), tellurium (Te), and polonium (Po).

Noble Gases

The noble gases family is the 18th family in the periodic table. It includes helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Rn). They are called noble gases because they do not generally form compounds with other elements. They are unreactive because their outer orbits are completely filled with electrons. No natural compounds formed from these gases exist. All noble gases are gases at room temperature.

Hydrogen is a special case because it is a family of one. Sometimes hydrogen behaves as a metal and sometimes as a non-metal. Hydrogen has one electron in its only occupied orbit, so it is reactive. Almost all of the hydrogen on earth is combined with other materials. Hydrogen is a gas at room temperature.

You should be able to predict with some accuracy the properties of elements that are in the same families. If you received a sample of krypton, you should be able to tell someone about that element without studying it in the laboratory.

Rows in the Periodic Table

Rows in the periodic table are called **periods** (see Figure 2.18). Elements in periods do not demonstrate similar properties as they do in families. Periods, however, show trends. As you look from the left side to the right side of period 2 of the table, the elements change from metals (Li) to non-metals (C) and to gases (Ne).

Learning Activity 2.11: The Periodic Table

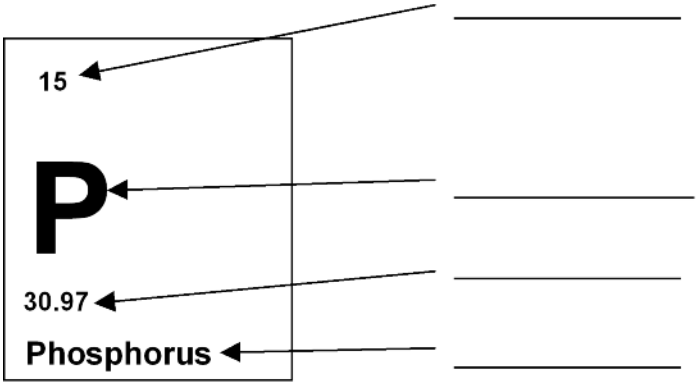
1. Construct a concept map that includes
   - periodic table
   - atom
   - electrons
   - protons
   - neutrons
   - atomic number
   - atomic mass
   - mass number

   You may include other words and/or connecting phrases to make your concept map meaningful.
2. Describe where the following are found on the periodic table:
   a. metals
   b. non-metals
3. What would happen if fluorine
   a. gained a proton?
   b. lost a proton?
4. Make a hypothesis about the effect of fluorine's losing an electron. Pay careful attention to the number of protons and electrons in this case.
5. An element has been identified and you know it is an alkali metal.
   a. Predict whether it will be a solid, liquid, or gas at room temperature.
   b. Predict the number of electrons in its outer orbit.
   c. Predict its possible atomic number(s).
   d. Explain the basis of your predictions.
6. An element has been identified and all you know is that it is a noble gas.
   a. Predict the state of this new noble gas at room temperature.
   b. Predict the number of electrons in its outer orbit.
   c. Predict its possible atomic number(s).
   d. Explain the basis of your predictions.

continued

Learning Activity 2.11 (continued)

7. Draw Bohr models for the first two alkali metals, the first two halogens, and the first two noble gases.
8. Using the periodic table, answer the following questions.
   a. How many orbits are there in the elements in the third row (period)?
   b. How many orbits are there in the elements in the fourth period?
   c. What conclusion can you draw about the periods on the periodic table and the number of orbits the elements have in that period?
9. Why is hydrogen not considered part of the alkali metals but is seen to be a family of one?
10. a. List the elements along the third period of the periodic table.
    b. If you were to examine the properties of elements from the left to the right side of a periodic table (a period), how would you describe changes in their
       i. state?
       ii. atomic number?
       iii. number of protons?
       iv. number of electrons?
11. Identify the facts from the sample element in the periodic table as shown below.



Check the answer key.

Learning Activity 2.12: Elements, Atoms, and the Periodic Table

This learning activity will give you an opportunity to check your progress on all of the material covered so far.

1. State the similarities and the differences in Dalton's model of the atom and Bohr's model of the atom (three similarities and three differences).
2. Describe briefly how Thomson, Rutherford, Moseley, and Chadwick added to Dalton's model of the atom.
   a. Thomson
   b. Rutherford
   c. Moseley
   d. Chadwick
3. Draw a Bohr atom for neon and label the nucleus and electrons. Use a periodic table to find information about neon, and label the number of protons and neutrons in the nucleus.
4. Use the terms *atomic number* and/or *mass number* to describe the following:
   a. Number of electrons
   b. Number of neutrons
   c. Number of protons
5. You are given the atomic number and the mass number of the five elements shown below. From this information, complete the table.

Name	Atomic Number	Mass Number	Symbol	Number of Protons	Number of Neutrons	Number of Electrons
Boron	**5**	**11**				
Sulphur	**16**	**32**				
Barium	**56**	**137**				
Gold	**79**	**197**				
Uranium	**92**	**238**				

6. Draw the nucleus of lithium. Make a large nucleus so you can draw the protons and neutrons inside it. The atomic number of lithium is 3 and the mass number is 7.

continued

Learning Activity 2.12 (continued)

7. A sample of an element showed that it had an atomic number of 17 and an atomic mass of 35.
   a. Draw a Bohr model of the atom.
   b. What is the name of the element?
   c. To what family does the element belong?
   d. Is the element reactive?
   e. How many electrons does the element need to fill its electron shell?
8. Answer the following questions about the periodic table.
   a. To whom do we give credit for developing the periodic table?
   b. How are elements arranged in a modern periodic table?
   c. What is periodicity?
   d. What can be said about the elements that are grouped in columns?
   e. What name is given to the elements in columns in a periodic table?
   f. What can be said about the elements grouped in a row in a periodic table?
   g. What name is given to the row of elements in a periodic table?
   h. Why are elements in columns I (1) and VII A (17) so reactive but those in column VIII A (18) are not?
   i. What name is given to column VIII A (18) elements?
   j. How is the periodic table helpful?
9. A new element was discovered. The element has one electron in its outer shell.
   a. What family does it belong to?
   b. Is it likely to react with water?
10. Place true (T) or false (F) beside each of the following statements.
    a. The mass number of an atom is equal to the mass of the protons plus the mass of the electrons.
    b. Most of the atom is empty space.
    c. Most of the mass of an atom is concentrated in the electrons around the nucleus.
    d. Rutherford discovered that about one in 8000 positive bullets would bounce back from the gold foil.

continued

Learning Activity 2.12 (continued)

e. The atomic number plus the number of electrons equals the mass number of an atom.

f. Aluminum has an atomic number of 13 and a mass number of 27 so it has 14 electrons.

g. Dalton was right when he said that atoms cannot be divided because atoms are too small to see.

Check the answer key.

Summary

- The problems with Mendeleev's periodic table were overcome when Moseley discovered the positive protons in the nucleus. The number of protons was called the atomic number of the atom.
- When elements are arranged according to atomic number, the properties and characteristics can be predicted.
- The modern periodic law states that the properties of elements are a periodic function of their atomic numbers.
- The periodic table is designed to give key facts about the elements. The atomic number, symbol, atomic mass, and name of the element are common pieces of information in a periodic table.
- Families are grouped in columns in a periodic table. These elements have common characteristic properties.
- Rows or periods in a periodic table show trends in characteristic properties.

Lesson 11: Metals, Non-metals, and Metalloids

Lesson Focus

After completing this lesson, you will be able to

- ☐ After completing this lesson, you will be able to
- ☐ use the periodic table to differentiate among metals, non-metals, and metalloids
- ☐ classify elements as metals, non-metals, or metalloids based on their properties
- ☐ describe the properties of metals, non-metals, and metalloids

Key Words

- properties
- physical properties
- chemical properties
- metals
- lustre
- malleable
- ductile
- non-metals
- metalloids

Online Resources

The following website provide information about metals, non-metals, and metalloids..

- Natural Resources Canada
  www.nrcan-rncan.gc.ca/mms-smm/index-eng.htm
  This site describes minerals and metals in Canada.

- Oracle Education Foundation
  http://library.thinkquest.org/3659/pertable/
  This site provides a description of metals, non-metals, and metalloids.

In the previous section you studied the organization of the periodic table. The arrangement of the families and periods has elements with similar properties and characteristics grouped together.

Properties

The defining characteristic of any object can be thought of as its **properties**. Elements in the periodic table are frequently described by their **physical properties** and **chemical properties.**

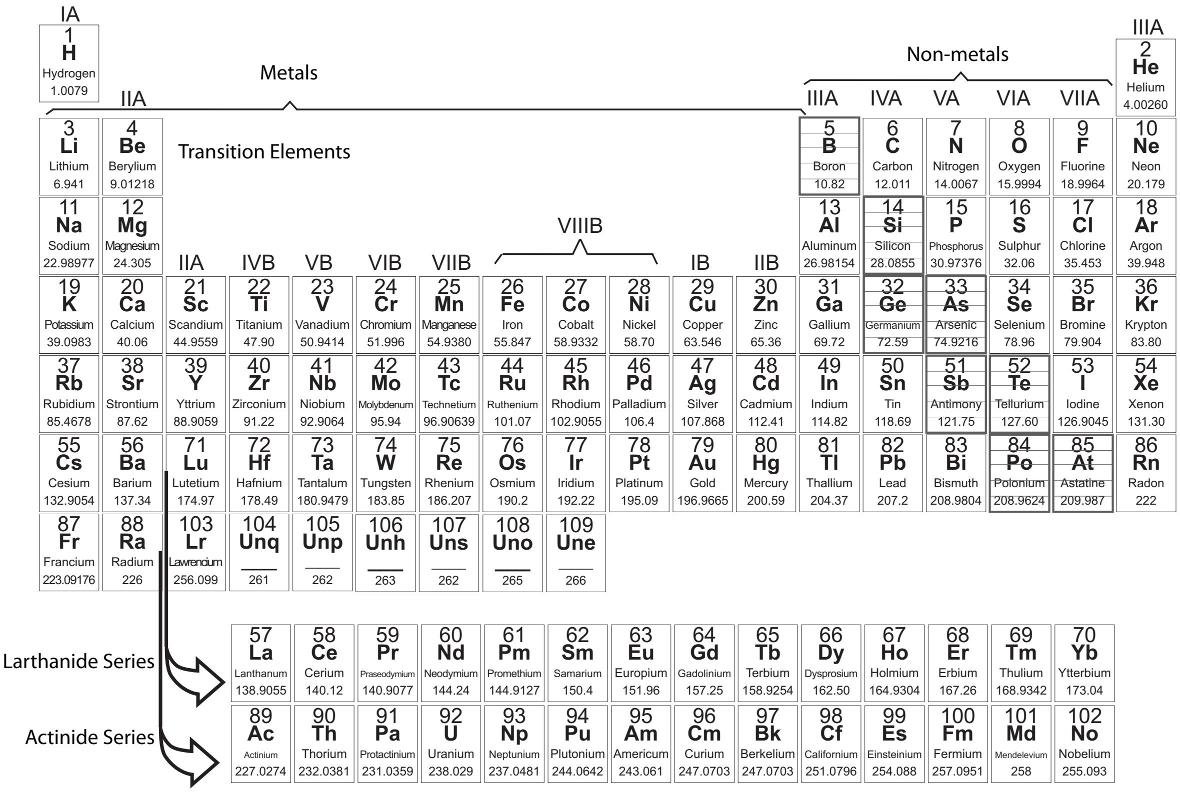
Physical properties are the characteristics of an element or compound that can be measured or observed without changing the composition of the element or compound. Some common examples of physical properties include state, colour, conductivity, density, ductility, malleability, mass, solubility, lustre, and volume.

Chemical properties are the characteristics of an element or compound that are measured or observed during a chemical reaction. Some common examples of chemical properties include reactivity (with other substances) and chemical stability.

Metals, Non-metals, and Metalloids in the Periodic Table

The periodic table can give us a picture of how elements are grouped according to characteristic properties. The periodic table below (Figure 2.20) shows several groups of elements: metals, non-metals, and metalloids. Brackets at the top of the table identify metals and non-metals. Boxes with horizontal lines identify metalloids. Notice that metalloids form steps with metals on the left and non-metals on the right.

Figure 2.20 **The Periodic Table**



IA	IIA	IIA	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	IIIA
1 **H** Hydrogen 1.0079																	2 **He** Helium 4.00260
3 **Li** Lithium 6.941	4 **Be** Berylium 9.01218											5 **B** Boron 10.82	6 **C** Carbon 12.011	7 **N** Nitrogen 14.0067	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9964	10 **Ne** Neon 20.179
11 **Na** Sodium 22.98977	12 **Mg** Magnesium 24.305											13 **Al** Aluminum 26.98154	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.97376	16 **S** Sulphur 32.06	17 **Cl** Chlorine 35.453	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.06	21 **Sc** Scandium 44.9559	22 **Ti** Titanium 47.90	23 **V** Vanadium 50.9414	24 **Cr** Chromium 51.996	25 **Mn** Manganese 54.9380	26 **Fe** Iron 55.847	27 **Co** Cobalt 58.9332	28 **Ni** Nickel 58.70	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.36	31 **Ga** Gallium 69.72	32 **Ge** Germanium 72.59	33 **As** Arsenic 74.9216	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.9059	40 **Zr** Zirconium 91.22	41 **Nb** Niobium 92.9064	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium 96.90639	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.9055	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.868	48 **Cd** Cadmium 112.41	49 **In** Indium 114.82	50 **Sn** Tin 118.69	51 **Sb** Antimony 121.75	52 **Te** Tellurium 127.60	53 **I** Iodine 126.9045	54 **Xe** Xenon 131.30
55 **Cs** Cesium 132.9054	56 **Ba** Barium 137.34	71 **Lu** Lutetium 174.97	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.85	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.22	78 **Pt** Platinum 195.09	79 **Au** Gold 196.9665	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.37	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.9804	84 **Po** Polonium 208.9624	85 **At** Astatine 209.987	86 **Rn** Radon 222
87 **Fr** Francium 223.09176	88 **Ra** Radium 226	103 **Lr** Lawrencium 256.099	104 **Unq** 261	105 **Unp** 262	106 **Unh** 263	107 **Uns** 262	108 **Uno** 265	109 **Une** 266									

Larthanide Series	57 **La** Lanthanum 138.9055	58 **Ce** Cerium 140.12	59 **Pr** Praseodymium 140.9077	60 **Nd** Neodymium 144.24	61 **Pm** Promethium 144.9127	62 **Sm** Samarium 150.4	63 **Eu** Europium 151.96	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.9254	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.9304	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.9342	70 **Yb** Ytterbium 173.04
Actinide Series	89 **Ac** Actinium 227.0274	90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.0359	92 **U** Uranium 238.029	93 **Np** Neptunium 237.0481	94 **Pu** Plutonium 244.0642	95 **Am** Americum 243.061	96 **Cm** Curium 247.0703	97 **Bk** Berkelium 247.0703	98 **Cf** Californium 251.0796	99 **Es** Einsteinium 254.088	100 **Fm** Fermium 257.0951	101 **Md** Mendelevium 258	102 **No** Nobelium 255.093

Metals

Metals are the most common form of matter. About 75 percent of the periodic table is made of metallic elements. You will notice from Figure 2.20 that metals occupy the left and middle part up to the metalloids.

Metals demonstrate similar physical properties.

- **lustre** (all metals are shiny)
- silver-grey colour (gold and copper are exceptions)
- **malleable** (metals can be hammered into very thin sheets)
- **ductile** (metals can be drawn into a wire)
- solid (metals except mercury are solid at room temperature)
- conduct heat (metals are capable of transferring heat along their length)
- conduct electricity (metals are able to conduct electric current along their length)

All metals do not possess these characteristics to the same degree. For example, gold is extremely malleable. For centuries, artisans have hammered gold into sheets that are only a few molecules thick. In this way, a small lump of gold can be transformed into a large sheet of gold. If you remember in an earlier section, Rutherford fired alpha particles at such a sheet of gold and determined that atoms are mainly space with a small dense nucleus.

Copper is used for electric wiring as it is the second best conductor and is ductile. A better conductor of electricity is silver but it is too expensive to use for house wiring.

Non-metals

Non-metals are located on the right-hand side of the periodic table. About 15 percent of all elements in the periodic table are non-metals. Non-metals demonstrate properties that are the opposite of metals.

- Non-metals have no lustre.
- Non-metals are brittle; they are not malleable or ductile.
- Non-metals are insulators or nonconductors of heat and electricity (graphite, a form of carbon, is the only non-metal that conducts electricity).
- Non-metals are either a solid or gas at room temperature, except for bromine which is a liquid.

Metalloids

Metalloids are located on a staircase of elements located between metals and non-metals. Metalloids make up about 6 percent of all the elements in the periodic table. As you might expect, metalloids demonstrate some properties of metals and some properties of non-metals.

- Metalloids are all solid at room temperature.
- Some metalloids have lustre.
- Metalloids tend to behave like non-metals in their physical and chemical properties, except they can conduct electricity to some extent.
- Metalloids are semiconductors, used in the electronics industry for components and microchips.

Learning Activity 2.13: Metals, Non-metals, and Metalloids

1. Name three characteristics of
   a. metals
   b. non-metals
   c. metalloids
2. You have an object that exhibits the following characteristics:
   - It is a shiny silver colour.
   - It can be shaped into long, thin strips.
   - It is a solid.

   Is this object a metal, non-metal, or metalloid? Explain.

continued

Learning Activity 2.13 (continued)

3. You have an object that exhibits the following characteristics:
   - It breaks easily when hammered.
   - It conducts electricity.
   - It is a solid.

   Is this object a metal, non-metal, or metalloid? Explain.

Check the answer key.

Summary

- Elements and compounds can be classified according to their chemical and physical properties.
- Metals, non-metals, and metalloids are the three fundamental classifications for all materials.
- Metals occupy the left side of the periodic table, non-metals the right side, and metalloids separate them.
- Metals, non-metals, and metalloids have different properties that distinguish them from each other.

LESSON 12: REACTIVITY AND STABILITY OF CHEMICAL FAMILIES

Lesson Focus

After completing this lesson, you will be able to

- ☐ explain variations in chemical reactivity based on the position of the element in the periodic table
- ☐ explain why the alkali metals and the halogens are the most reactive families
- ☐ explain why the noble gases are generally unreactive
- ☐ explain why the outer shell of electrons (valence electrons) is thought to be the most important for determining chemical properties

Key Words

- valence electrons
- valence shells

Chemical Reactivity

When an element, the simplest form of a substance, is involved in forming a new material, a chemical reaction must take place. One family, however, called the noble gases is unreactive. They do not want to combine with another element to form a new substance. If you examine the periodic table, you can see that the noble gases have completely filled outer electron shells. The electrons found in the outer shell are called **valence electrons,** and the outer orbital is called the **valence shell.** We might generalize and say the following:

- Noble gases all have completely filled outer electron shells, and they are unreactive.
- When any element has a completely filled outer electron shell (valence shell), it does not want to react with any other substance.
- Other elements want to react chemically to form new materials. Other elements do not have completely filled valence shells. It seems that chemical reactivity has something to do with electron shells that are not completely filled.

- The most reactive elements are those in the alkali family, which have one electron in the outer electron shell, and the halogen family, which are one electron short of a filled electron shell. The alkali family needs to lose just one electron to have a filled electron shell and the halogen family needs to gain one electron to have a filled electron shell.
- Chemical reactivity appears to be related to the number of electrons that need to be gained or lost by an element to have its outer electron shell completely filled. The less the number needed, the greater the reactivity of the element.
- Outer shell electrons are involved in any chemical reaction.
- When a chemical reaction takes place and one element combines with another to form a new substance, there must be some movement of outer shell electrons.

Chemical reactivity is based on the need for an element to have its valence shell completely filled. Completely filled electron shells in any element will occur when one element combines with another element or another atom of the same element.

Learning Activity 2.14: Chemical Reactivity

1. Complete the following table. Use high, moderate, and zero for reactivity.

Rating the Reactivity of Chemical Families

Element	Reactivity	Electrons Gained or Lost	# of Electrons Gained or Lost	Family
Magnesium				
Nitrogen				
Argon				

2. Determine the following:
   a. An element has high reactivity and it gains one electron. It belongs to the _________________ family.
   b. An element has no reactivity. It belongs to the ________________ family.
   c. An element has moderate reactivity and it loses 2 electrons. It belongs to the __________________ family.

continued

Learning Activity 2.14 (continued)

3. Using your knowledge of reactivity and electron movement, explain what you think happens when sodium metal and chlorine gas are placed in a container and heated. Draw a Bohr diagram to help explain the result.

Check the answer key.

Summary

- Every atom of an element desires to have a full outer electron shell, that is, to have the same electron configuration as a noble gas.
- Electrons in the outer electron shell are called valence electrons.
- Metals will lose electrons and non-metals will gain electrons in order to have full electron shells.
- When atoms lose or gain electrons, they are involved in a chemical reaction.
- In addition to giving electrons away or taking them in, atoms can share electrons.

Whenever elements combine in a chemical reaction to form a new substance, the elements all have outer electron shells that are filled.

Notes

Assignment 2.3: Chemical Reactivity on the Periodic Table (41 marks)

1. Complete the following table. Use high, moderate, and zero for reactivity. *(0.5 mark each = 12 marks)*

Rating the Reactivity of Chemical Families				
Element	Reactivity	Electrons Gainedor Lost	# of Electrons Gained or Lost	Family
Hydrogen				
Aluminum				
Sodium				
Fluorine				
Sulphur				
Calcium				

2. Explain which group of elements would provide the best material for electrical wiring in houses: metals, non-metals, or metalloids. Refer to element properties to justify your reasoning. *(4 marks)*

3. Using your knowledge of elements and reactivity, explain why sodium metal must be kept submerged in oil and not exposed to the atmosphere. *(2 marks)*

4. A sample of an unidentified element shows that it has an atomic number of 16 and an atomic mass of 32. *(4 marks)*

   a. Draw a Bohr model of the atom.

   b. What is the name of the element? ______________________________

   c. To which family does the element belong? ______________________

   d. How many electrons does the element need to fill its electron shell? ____

5. Complete the table below. *(10 marks)*

Name	Atomic Number	Mass Number	Symbol	Number of Protons	Number of Neutrons	Number of Electrons
		207	**Pb**			**82**
	35			**35**	**45**	
Silver					**61**	**47**
		201	**Hg**	**80**		
	19		**K**		**20**	

6. An unknown element has been identified as an alkaline-earth metal. Describe its physical state at room temperature and the number of electrons in each atom's outer orbit. List the possible atomic numbers of this element. *(3 marks)*

____

____

____

____

____

7. Describe the similarities and differences in Dalton’s model of the atom and Bohr’s model of the atom. (*6 marks)*

Notes

LESSON 13: WHAT IS A COMPOUND?

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe the difference between an element and a compound, an and atom and a molecule
- ☐ name a variety of chemicals in use every day and describe how they are used

Key Words

- element
- compound
- atom
- molecule

In Lesson 4, you learned about Dalton's Atomic Theory. Recall that

- all matter is made of atoms
- each element has its own kind of atom
- compounds are formed when different elements link together to form new material
- atoms cannot be created or destroyed

His theory can help us to understand the differences between elements and compounds.

Composition of Elements, Compounds, Atoms, and Molecules

Some substances are made of one element. Copper, lead, and aluminum are all metals made of one element. Neon in brightly lit signs is a gaseous element. The mercury in thermometers is a liquid element. Most substances, however, are **compounds** made by combining two or more elements. Steel, rubber, nylon, and sugar are all compounds, or mixtures of compounds, made from elements that are joined together in a precise way.

An element is the simplest form into which any material can be broken down. It is impossible to break the element gold down into something simpler than gold.

An **element** is a pure substance whose molecules are made up of identical atoms.

While gold is the simplest form of a material, it is not the smallest amount; that is, it is possible to have a 20-gram sample of gold or a 2-gram sample of gold. Both samples are gold. It is theoretically possible to divide the 2-gram sample of gold in half and then in half again, and so on, until a point is reached where we are left with one particle of gold that cannot be further divided. This smallest particle of an element is called an **atom.**

An element is the simplest form of a material; an atom is the smallest particle of an element. It is possible to have one atom of gold.

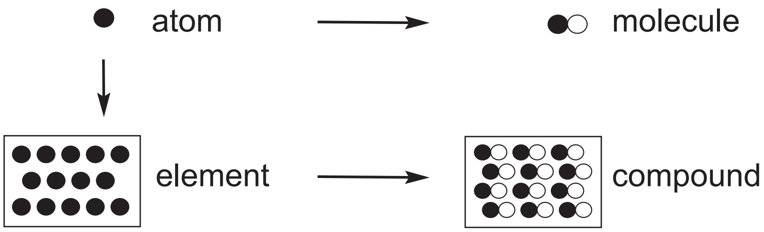
It is possible to take one atom of chlorine and one atom of sodium, heat them, and have them form a compound of sodium chloride. Sodium is an extremely reactive metal. Sodium must be immersed in oil to keep it from any water, even water vapour, as it will react violently. Chlorine exists as a gas at room temperature. Chlorine is poisonous. It is so poisonous that it was used as a gas to attack troops in the First World War. Chlorine gas caused many deaths and damaged the lungs of many soldiers for the remainder of their lives. These ferocious sounding elements will combine to form a compound called sodium chloride or table salt. You can see that a compound can have totally different characteristics from the elements that formed the compound. A compound is the simplest form of a material that contains elements in a fixed proportion often with different properties than the elements from which it is formed. A **compound** is a pure substance whose molecules are made up of different kinds of atoms. Compounds can be broken down into simpler substances called elements.

If you had a special microscope and scalpel, you could repeatedly divide a grain of sugar in half until it is eventually just a single particle that could not be further divided. This particle would be a molecule.

A compound is the simplest form of any material containing two or more elements. A **molecule** is the smallest particle of a compound. It is possible to have one molecule of sodium chloride. A molecule is composed of a cluster of atoms and can be broken down into those atoms during a chemical change.

Elements form compounds (atoms form molecules) in a process called a chemical reaction.

Figure 2.21 **Chemical Reaction**



A chemical reaction is the process of one atom releasing one or more electrons and another atom receiving one or more electrons. For example, when sodium chloride is formed, sodium releases one electron and chlorine receives one electron. In the process of releasing one electron, sodium gains the electron configuration of a noble gas—neon—and is chemically stable. In the process of receiving an electron, chlorine also gains the electron configuration of a noble gas. In this case, it is also neon and is chemically stable. In the process of giving off or receiving an electron, the two atoms unite to form the molecule sodium chloride. There is much more to learn about the process of atoms combining to form molecules, but we will leave that for another science course.

Learning Activity 2.15: Compounds

1. Scientists have identified about 10 million pure substances. All these pure substances are formed by 109 elements. Explain how it is possible for so many substances to be formed by such a small number of elements.
2. Try explaining why sodium and chlorine have such different properties when they exist as elements from when they exist as the compound sodium chloride.
3. Name 10 compounds/chemicals found in your home. These chemicals can be found in everything from food to cleaning products.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

continued

Learning Activity 2.15 (continued)

f. ____

g. ____

h. ____

i. ____

j. ____

4. Distinguish between an
   a. element and a compound
   b. atom and a molecule

Check the answer key.

Summary

Element: the simplest form of a substance

Atom: the smallest particle of an element

Compound: the simplest form of any material containing two or more elements

Molecule: the smallest particle of a compound

- Atoms combine to form molecules (elements combine to form compounds) through chemical reactions.
- Molecules or compounds have different properties from the atoms or elements forming them.
- A chemical reaction involves the moving or sharing of electrons between atoms.

LESSON 14: CHEMICAL FORMULAS

Lesson Focus

After completing this lesson, you will be able to

- ☐ use a chemical formula to determine which elements form a compound
- ☐ interpret a chemical formula in terms of the elements present in the molecule and the number of atoms of each element

Key Words

- diatomic
- polyatomic
- chemical formula

Review of the Terms *Element* and *Compound*

Both elements and compounds are pure substances (i.e., they are the same throughout).

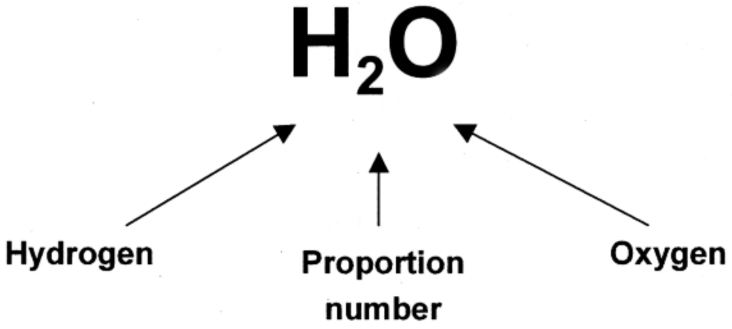
- Elements are made of a single kind of atom. Elements cannot be divided into simpler substances.
- Compounds are made of elements combined together in a specific way. The smallest particle of a compound is a molecule. Molecules are made of more than one kind of atom, so they can be broken down into simpler substances (e.g., water [H_20] can be broken down by electrolysis into hydrogen and oxygen). Compounds can be broken down into elements in several ways. Water is separated into its elements using electricity; copper sulfide is separated into copper and sulphur using heat.
- Many elements exist in their natural form as compounds made up of only one kind of element. Our atmosphere is made of such elements. Oxygen and nitrogen are the most abundant components of our atmosphere. Both these elements combine with themselves to form a **diatomic** molecule (oxygen O_2, nitrogen N_2). The difference between a stable and active element is the extent to which the outside electron shell is complete. Both oxygen and nitrogen are active atoms, but they are stable as compounds; if the two elements did not exist in the form of diatomic molecules, we would not be able to breathe as they would damage our lungs. **Polyatomic** molecules contain more than two atoms (e.g., P_4).

Chemical Formulas

Compounds are formed whenever two or more elements share or transfer electrons. The process in which compounds are formed is called a chemical reaction. Chemical reactions can occur when elements combine with each other or when compounds react together. For example, hydrogen and oxygen combine explosively to form water. The compounds sodium bicarbonate (baking soda) and vinegar (acetic acid) react to form sodium acetate, water, and carbon dioxide. Carbon dioxide in baking is important for cooks who like to make light cakes.

A chemical formula is a shorthand method to show the elements that make up the compound and the proportions in which these elements combine to form the compound. Every compound has a definite set of proportions for each element as they combine.

Figure 2.22 **Chemical Formula**



In water, there are two atoms of hydrogen for every atom of oxygen.

In water (H_2O), for example, twice as many hydrogen atoms combine with oxygen atoms to form the compound. For one molecule of water, two atoms of hydrogen have combined with one atom of oxygen. Similarly, 20 atoms of hydrogen combine with 10 atoms of oxygen to form 10 molecules of water. The actual number of atoms of any given element in a sample of a compound is always equal to the number of molecules of the compound times the proportion number in the formula.

Consider the following example:

If we had three molecules of the compound carbon dioxide (CO_2), we would have a total of

- 3 molecules x 1 atom of carbon per molecule = 3 atoms of carbon and
- 3 molecules x 2 atoms of oxygen per molecule = 6 atoms of oxygen.

Learning Activity 2.16: Atoms

A form of sugar called glucose has the chemical formula $C_6H_{12}O_6$. From this formula, state the name of the elements and the number of atoms needed to make one molecule of glucose.

	Element name	Atoms
C	____________________	__________
O	____________________	__________
H	____________________	__________

Check the answer key.

Learning Activity 2.17: Number of Atoms

1. State the identity and the number of atoms of each element in the given number of molecules in the table below.

Table of Atoms Forming Compounds

Compound	# of Molecules	Element Names	# of Atoms of each Element
$KHCO_3$	1 molecule		
$AlCl_3$	3 molecules		
CBr_4	6 molecules		
H_2SO_4	5 molecules		
$C_{11}H_{22}O_{12}$	4 molecules		

2. A sample of air is brought into the lab and analyzed (taken apart). The sample was found to contain the following materials. State whether the components are in the form of an atom or a molecule.

Atom or molecule

a. oxygen (O_2) ________________
b. oxygen (O_3) ________________
c. carbon dioxide (CO_2) ________________
d. carbon monoxide (CO) ________________
e. nitrogen (N_2) ________________
f. argon (Ar) ________________
g. methane (CH_4) ________________

continued

Learning Activity 2.17 (continued)

3. Why is it important for scientists, who communicate with each other all over the world, to have a uniform set of chemical symbols?
4. Place the letter for the correct answer in the space at left.

_____	simplest form of a pure substance	a. Al
_____	atoms combined in a specific way	b. CO_2
_____	electrons in the outer electron shell	c. molecule
_____	diatomic molecule	d. atom
_____	ozone	e. He
_____	two or more materials combined to produce a new substance	g. valence electron
_____	carbon dioxide	h. O_3
_____	aluminum	i. compound
_____	is stable since the outer electron shell is filled	j. element

Learning Activity 2.17 (continued)

5. **Chemical Formulas**—For each of the molecules in the left column, answer the questions that appear in the other columns.

Chemical Formula	a. How many different kinds of atoms are in this molecule? b. How many atoms of each kind are in this molecule?) c. What is the total number of all atoms in this molecule?	Which of the following does this molecule represent?
Na_2O	a. b. c.	■ a pure substance ■ a compound ■ an element ■ a diatomic molecule ■ a polytomic molecule
H_2	a. b. c.	■ a pure substance ■ a compound ■ an element ■ a diatomic molecule ■ a polytomic molecule
Al	a. b. c.	■ a pure substance ■ a compound ■ an element ■ a diatomic molecule ■ a polytomic molecule
S_8	a. b. c.	■ a pure substance ■ a compound ■ an element ■ a diatomic molecule ■ a polytomic molecule

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Check the answer key.

Summary

- Elements are the simplest form of any material. An element is a pure substance that cannot be broken down further by chemical action.
- A compound is made of elements that have combined together in a definite proportion. Whenever elements combine to form a compound, there is always a transfer or sharing of electrons between the atoms that make up the compound.
- A chemical formula represents the atoms that make up the compound and the proportion in which they combine (e.g., $AlCl_3$ shows that aluminum and chlorine have combined to form a compound, and the formula also indicates that for every atom of aluminum that has combined to form the compound, there are three atoms of chlorine).
- Chemical formulas describe the number of atoms used to form a single molecule or any number of molecules. Molecules are names that refer to the smallest unit of a compound
  (e.g., H_2CO_3). This formula indicates that one molecule of carbonic acid contains two atoms of hydrogen, one atom of carbon, and three atoms of oxygen. Three molecules of carbonic acid would contain three times as many atoms of each type (six atoms of hydrogen, three atoms of carbon, and nine atoms of oxygen).

Notes

LESSON 15: PROPERTIES OF SUBSTANCES

Lesson Focus

After completing this lesson, you will be able to

☐ evaluate materials and determine possibilities for their use based on their properties

☐ identify both positive and negative considerations for using a material

Key Words

- physical properties
- state
- hardness
- alloy
- malleability
- brittle
- ductility
- melting point
- boiling point
- viscosity
- density
- density
- solubility
- solvent
- chemical properties
- combustible

Introduction

Properties of materials were introduced in Grade 5. We will take this opportunity to discuss them more fully.

Properties of materials, both elements and compounds, are important for science and technology. As consumers, we make choices based on the properties of matter. For example, if you are a mountain biker, you might choose your bike based on materials that are the strongest and lightest you can afford.

In this lesson, you will review properties of materials and look at some reasons why it is important to know their properties.

Properties of Materials

1. Physical Properties

Physical properties are characteristics that exist in a material.

- **State**

The state of a substance—whether it is a gas, a liquid, or a solid—is a characteristic property. Temperature usually accompanies the state of a material. For example, many tables indicate the state of a substance at room temperature.

Propane condenses (changes from gas to liquid) at –42°C. Propane's condensation temperature means our cold Canadian winters can change the propane in a tank from gas to liquid. If you are using a propane furnace, it will quit working at these low temperatures. You would need to go outside and heat the propane tank in order to convert the propane back to a gas and get your furnace working again.

Our Canadian winters are also capable of making us reconsider what kind of thermometer we use. A mercury thermometer might not properly record extremely cold temperatures. Mercury freezes at –38.9°C; it is possible for northern communities to experience this temperature during winter, causing a problem reading an accurate temperature.

- **Hardness**

Hardness refers to a material's ability to resist being scratched or dented.

You may have seen a movie where an old-timer bites a piece of gold to determine its purity. This is not a good practice, but he knew that pure gold is quite soft for a metal and he should be able to dent it with his teeth. An **alloy** is a mixture containing a metal which is generally used to maintain some properties of the metal while changing some of its other properties. Alloys of gold are harder and not as easily dented. Hardness was used to determine the purity of gold. Pure carbon can exist as diamond, one of the hardest materials, and graphite, one of the softest materials.

- **Malleability**

Malleable materials are capable of being hammered or rolled into thin sheets. Metals such as gold and silver are malleable. Materials that are not malleable can be **brittle** (easily cracked or fractured). Glass is brittle.

- **Ductility**

Ductility is a measure of the ability of a material to be drawn into a wire. You have already learned that some metals are ductile.

■ Melting point and boiling point

Melting and boiling points are measurable properties and they are also characteristic of materials. Water melts at 0°C and boils at 100°C. The melting point and boiling points of water distinguish it from all other materials. Sometimes it is important to identify unknown materials. An analysis of their melting and boiling points can often quickly identify them.

■ Viscosity

Viscosity refers to the ability of a material to flow. We know from experience that water flows more easily than corn syrup, so we can describe corn syrup as having a greater viscosity.

■ Density

Density is a measure of a material mass per unit volume. A common way to describe density uses grams per cubic centimetre (g/cm^3). Sometimes density is misunderstood. The term "heavy" is used to mean density. For example, someone might say lead is heavier than water. This statement might be true in one example, but it is easy to see that a barrel of water is heavier than a small piece of lead.

We can correctly say that lead is denser than water. Water has a density of 1 g/cm^3 whereas lead has a density of
11.34 g/cm^3. It doesn't matter whether we have a barrel or a teaspoon of water, its density is always the same and always less than lead.

The density formula is

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad \text{or} \qquad \mathbf{D} = \frac{\mathbf{M}}{\mathbf{V}}$$

■ Solubility

Some substances such as sugar dissolve easily in water. These substances are called soluble. Some substances such as iron filings do not dissolve in water. These substances are called **insoluble**. Water is the **solvent** in these examples. A solvent is a substance capable of dissolving another substance. Alcohol is used as a solvent in some medicines. Alcohol is used since it can dissolve some solutes that are not soluble in water.

2. Chemical Properties

Chemical properties describe the behaviour of a substance as it reacts with another substance to form new materials. Listed below are some characteristics of chemical change.

- When two or more chemicals combine they sometimes burn— that is, they are **combustible**. An example of combustibility occurs when hydrogen and oxygen combine. A spark will cause them to combine explosively to form water.
- Some substances change colour when exposed to air. Silver will turn black.
- Some substances will react with water. Lithium will give off a gas, make sparks, and fizz.
- Some materials react with acids. A penny will disappear in nitric acid.
- Some substances react to heat. Whenever you have an egg for breakfast, a chemical reaction activated by heat takes place. The protein in the egg has changed into a different protein that is no longer clear and runny, but white and solid.

The two lists above represent the properties, both physical and chemical, that materials can possess. Some other properties require consideration since they include how well the material adapts to manufacturing and how desirable the characteristics are for the consumer. All these considerations help us determine the usefulness of the material, its cost in terms of development and disposal, how safe it is in both the short term and long term, and the durability of the material.

The considerations listed in the previous paragraph provide us with some tools to determine whether a product is worth developing. In every case, knowing the properties of materials helps us

- determine how a substance can be used
- determine whether the substance should be used after considering environmental and health concerns

The second point is becoming more important as population densities increase. The accumulation of industrial waste and our own garbage has a serious impact on the environment.

Water quality has become an important issue in many communities in Manitoba and Canada as they are experiencing deteriorating water quality from agricultural and industrial pollution. Water quality is also an issue for fish and wildlife in our rivers and lakes.

Air quality had been an issue in Winnipeg as a Manitoba Hydro generating station that used coal seemed to be causing considerable environmental damage. It has since been converted to use natural gas, the cleanest of all fossil fuels.

It must be noted that government and industry are becoming much more ready to act quickly when these issues arise. The refrigerant used in all air conditioning and refrigeration units has been found to have a seriously negative impact on the ozone layer. You will notice that government regulations are now in place to make certain all new vehicles are equipped with a refrigerant that has no impact on ozone. Anyone getting rid of a refrigerator must have the refrigerant removed by a professional before taking it to a dump.

You can see that properties of materials are important in determining whether they are useful and desirable in our society.

Learning Activity 2.18: Properties of Substances

1. What are the properties of the following substances that make them important for the stated uses?
    a. Diamond is used in drill bits that travel through rock.
    b. Helium is used to fill blimps.
    c. Hydrogen is not used to fill blimps.
    d. Copper is used in house wiring.
    e. Some cooking pots have a copper bottom.
    f. Electrical wires are covered in a plastic coating.

2. Describe what properties were responsible for stopping the use of the following materials. There is a brief report included with each question that will give you information to help answer the question.
    a. **Polychlorinated biphenyls (PCBs) in cooling electric transformers**

       PCBs are mixtures of synthetic organic chemicals with the same basic chemical structure and similar physical properties ranging from oily liquids to waxy solids. Due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment, as plasticizers in paints, plastics, and rubber products, in pigments, dyes, and carbonless copy paper, and many other applications. More than 1.5 billion pounds of PCBs were manufactured in the United States prior to cessation of production in 1977.

    The debate rages as to whether these compounds lead to human disease.

continued

Abdominal fat tissue from people who succumbed to different types of cancers showed about twice the level of PCBs and DDE (a DDT metabolite) than abdominal fat tissue from people who died from other causes. However, these chemicals were not found to be higher in samples from women with breast cancer as compared to women without breast cancer.

b. **Chlorofluorocarbons (CFCs) in air conditioners**

Members of the chlorofluorocarbon family are either gases or liquids at room temperature. Because they are non-toxic, non-flammable, and non-corrosive, they are used as propellants and refrigerants. They also put the "foam" in Styrofoam. The related bromofluorocarbons are effective, non-toxic fire extinguishing agents. All of these substances are human-made. All were released into the environment over the last 60 years at a rate of hundreds of thousands of metric tons per year. Research done in the mid-1970s linked the observed decrease in stratospheric ozone with the chemistry of the chlorofluorocarbons and caused a public outcry.

c. **Lead in gasoline** Today's good idea may bring tomorrow's crisis. Leaded gasoline is a notable example. Refineries in the early years of the twentieth century were unable to produce the higher quality gasolines demanded by ongoing improvements in engine design. Mechanical wear engendered by the relentless action of engine "knock" threatened to ruin automobile engines and, of course, was potentially catastrophic for the fledgling aircraft industry. (Today, better refining techniques produce a gasoline with lessened knock.) One option was to include a gasoline additive. Another alternative, ethanol, also called grain alcohol, may have been squelched by economic and political pressure from the petroleum industry. At any rate, gasoline became the fuel of choice for the internal combustion engine. In December 1921, Thomas Midgley of the General Motors Research Laboratory found that addition of tetraethyl lead provided an inexpensive means of eliminating engine knock. (Lead, a soft metal, lubricates intake and exhaust valve seats, preventing them from prematurely wearing down, a process known as valve seat recession.) Tetraethyl lead thus lent part of its name to the new product. Leaded gasoline became known as ethyl gasoline. Unfortunately, lead also tends to coat the rest of the engine and, for good measure, will coat the exhaust system as well. This was clearly not in the best interests of automotive efficiency, so a means of removing excess lead was devised: adding the lead scavengers ethylene dibromide and ethylene dichloride to the gasoline.

continued

Learning Activity 2.18 (continued)

Discharging pollutants into the environment has today come upon hard times in the form of increased citizen awareness and legislation. In the United States, following 20 years of gradual legislative reduction of lead in gasoline, the 1990 Clean Air Act Amendments finally banned alkylated lead compounds such as tetraethyl lead (and the closely related gasoline additive, tetramethyl lead) from use in on-the-road automobiles. However, these compounds are still allowed in gasolines used for propeller aircraft, recreation marine vehicles, and race cars. Many countries in Africa, Asia, Europe, and South America are still using lead additives in gasolines for all vehicles.

d. **Burning fossil fuels in electric generating plants**

One of the main causes of acid rain is sulphur dioxide. Natural sources which emit this gas are volcanoes, sea spray, rotting vegetation, and plankton. However, the burning of fossil fuels, such as coal and oil, are largely to be blamed for approximately half of the emissions of this gas in the world. When sulphur dioxide reaches the atmosphere, it oxidizes to first form a sulphate ion. It then becomes sulphuric acid as it joins with hydrogen atoms in the air and falls back down to earth in the form of acid rain. Oxidation occurs the most in clouds and especially in heavily polluted air where other compounds such as ammonia and ozone help to speed up the reaction, converting more sulphur dioxide to sulphuric acid. However, not all of the sulphur dioxide is converted to sulphuric acid. In fact, a substantial amount can float up into the atmosphere, move over to another area, and return to earth unconverted.

Check the answer key.

Notes

LESSON 16: PHYSICAL AND CHEMICAL CHANGES

Lesson Focus

After completing this lesson, you will be able to

- ☐ differentiate between physical and chemical changes
- ☐ identify chemical and physical changes and justify your choice

Key Words

- precipitate

Chemical and Physical Changes (Review)

In a physical change, the material remains the same even though its state or form has changed.

Solid dry ice (carbon dioxide) can change state from a solid directly to a gas. If the carbon dioxide vapour is collected and cooled enough, it will return to solid dry ice. Dry ice changing state is a good example of a physical change. A good test for physical change is to see if you can get the original substance back.

In a chemical change, the original substance is changed into a new material that has new properties.

Chemical changes include burning, rusting, and cooking. In each of these examples, it is difficult to return to the original materials. Once a piece of wood burns, the ash cannot be converted back to wood. This inability to change back to the original components is characteristic of chemical reactions.

Whenever you want to determine whether a physical or chemical reaction has taken place, you can check the following clues.

- **Has a new colour appeared?**

If you add red food colouring to water, there is no colour change. The food colouring and mixture of water and food colouring are the same colour. This is a physical change as no new compounds are created. If you allow a piece of iron to sit outside, it will change from a grey to a dull orange colour. A chemical change has taken place; the iron has changed to iron oxide.

- **Has heat or light been given off?**

When a candle burns, a chemical change, heat and light are given off. When you injure yourself in a sports game, you may be given an icepack. When you "crack" the ice pack, it starts to become cooler. This is a chemical change.

- **Are bubbles formed?**

When some chemicals are placed together, they react chemically to form bubbles of gas. An example would be the combination of a small amount of vinegar with baking soda. A chemical reaction results in the formation of carbon dioxide bubbles.

- **Does a solid appear in a liquid?**

When a solid, called a **precipitate**, appears after adding a chemical to a liquid, you can be confident a chemical reaction has taken place. You can blow a sample of carbon dioxide in a tumbler containing limewater. The carbon dioxide will cause the limewater to form a cloudy precipitate.

Mixing calcium hydroxide in water makes limewater. The calcium hydroxide solution reacts chemically with carbon dioxide to form the precipitate.

- **Is the reaction reversible?**

A blue material called bluestone is the common name for copper sulphate. When bluestone is heated, it loses its blue colour, becoming a grey solid. If water is added to the grey solid, it turns blue again. It appears there has been no chemical reaction as the original bluestone has returned.

If an egg is heated, it undergoes a transformation. After heating the egg we cannot make it return to its original material. A chemical reaction has taken place in the egg when it was heated.

Learning Activity 2.19: Identifying Chemical and Physical Changes

1. The table shown below lists some ordinary occurrences. In the second column, list whether each situation represents a physical or chemical change. In the third column, explain why.

Observed Action	Type of Change (P or C)	Explanation
a. Water boils out of a kettle or condenses on a cold glass.		
b. A silver spoon tarnishes.		
c. An aluminum pot is put on a burner and gets hot.		
d. Dry ice goes from a solid to a gaseous form of carbon dioxide.		
e. An iron rod rusts.		
f. Gold melts or solidifies.		
g. Sand is mixed in with salt.		
h. Methane burns.		
i. A piece of chalk is ground to dust.		
j. An antacid tablet neutralizes stomach acid.		
k. Glass breaks.		
l. Yeast is used to make carbon dioxide in bread and causes it to rise.		
m. A lump of sugar dissolves in water.		

continued

Learning Activity 2.19 (continued)

2. You are given two white liquids, each in a container. You are told one is milk and one is limewater in which carbon dioxide has bubbled through and formed a precipitate. Describe how you would show which container had the limewater.
3. Make a concept map for pure substances using the following terms: *atom, molecule, compound, element.*

Check the answer key.

Summary

It can sometimes be difficult to distinguish between chemical and physical changes. Remember to look for the following signs:

- Did a chemical reaction take place?
- Is the change permanent?
- Has there been a colour change?
- Has the substance warmed up or cooled off?
- Has light been given off?
- Are bubbles forming? Is a gas being given off?
- Has a solid formed that wasn't there before?

Use answers to these questions and what you already know about a substance to help you determine if a chemical or physical change has taken place.

LESSON 17: INDICATORS OF PHYSICAL AND CHEMICAL CHANGES

Lesson Focus

After completing this lesson, you will be able to

☐ list observations that indicate a chemical reaction has taken place

In the previous lesson, you learned about things to look for to determine whether an action is indicating a chemical or physical change. During this lesson, you will experiment with some of the indicators to determine the type of change. Try to base your answers on the observations that you make as well as your prior knowledge without letting this knowledge impair your judgment.

Summary

Chemical reactions are responsible for food, clothing, transportation, and entertainment. We can say every aspect of our lives is affected by chemical changes. Signs that indicate when a reaction has taken place accompany chemical changes. Some signals of chemical change include the following:

- colour change
- release of a gas
- production of heat/light
- production of a precipitate
- formation of a new substance

Notes

Assignment 2.4: Chemical and Physical Change Experiments (16 marks)

For this assignment, you must complete **one** of four hands-on experiments. Each experiment involves combining two substances and observing any changes that occur as they interact with each other.

Read over each experiment and choose the option that most interests you. For each option you must do the following:

- Gather the required materials to perform the experiment.
- Complete the Observations Report, recording the properties of your materials before and after the experiment, as well as any changes you notice while the materials are interacting.
- Classify the reaction. Using the information from previous lessons, decide whether your experiment involved a physical change, a chemical change, or no change at all. You must explain your reasoning using the indicators of physical and chemical changes.
- Answer the follow-up questions for your experiment. Some follow-up questions involve further experimentation, so don’t be too quick to toss out your materials!

You may wish to work on this assignment with a learning partner. If your learning partner is also registered in this course please submit your own work that is representative of your knowledge and understanding.

Observations Report *(10 marks)*

Reactants

Describe your starting materials. Consider colour, texture, shape, and state of matter. What do you notice?

Reaction Time

What happens as your reactants combine/interact? Are there any signs of physical or chemical change?

Products

Describe your final materials. How do they look and feel? How are they different from the reactants?

Classify

Did this experiment involve a physical change, a chemical change, or was there no change/reaction at all? Explain your reasoning.

Option 1: Salt and Water

Materials

- salt
- water
- teaspoon
- glass tumbler
- stir stick
- magnifying glass

What to Do

1. Take a few crystals of salt, and observe them carefully with a magnifying glass, noting the shape and size for your Observations Report.
2. Take a teaspoon of salt and add it to a tumbler of water. Give the salt a minute to settle naturally, recording any changes to the crystals and water.
3. To help combine the mixture, stir it with a spoon or stir stick.
4. Observe the stirred-up mixture by eye and with a magnifying glass, noting the properties of this product in your Observations Report.

Follow-Up Questions

Take a tablespoon of the salt/water mixture and place it in a shallow dish. Leave the mixture in the dish overnight and observe it again the next day, both by eye and with a magnifying glass.

1. What did you observe in the shallow dish? Compare your findings with the properties of salt written on your Observations Report. *(2 marks)*

2. When you checked on the dish, did it hold more or less substance than the previous day? How can you explain the added or lost material? *(2 marks)*

3. In winter, many Manitobans spread salt on their driveways or roads to help melt the buildup of ice. Use the results from your experiment to explain what happens to the road salt in the spring. *(2 marks)*

Option 2: Effervescent Antacid Tablets and Water

Materials

- 1 effervescent antacid tablet (e.g., Alka-Seltzer)
- water
- scraping tool (a pin, paper clip, file)
- glass tumbler
- magnifying glass

What to Do

1. Scrape off a little bit of powder from the tablet and observe it with a magnifying glass, noting the shape and feel for your Observations Report.
2. Add the tablet to a tumbler of water, and record any changes on your Observations Report.
3. Allow the tablet time to settle, and record the properties of the product on your Observations Report.

Follow-Up Questions

Take a tablespoon of the tablet/water mixture and place it in a shallow dish. Leave the mixture in the dish overnight, and observe it again the next day, both by eye and with a magnifying glass.

1. What did you observe? *(2 marks)*

   ____

   ____

   ____

2. Was there more or less substance in the dish? How can you explain this change? *(2 marks)*

   ____

   ____

   ____

3. Did the tablet and water form a uniform mixture (the same throughout), or did there appear to be several parts or layers? Was it completely liquid, or were there any precipitates (solid elements)? *(2 marks)*

   ____

   ____

   ____

Option 3: Candle Wax and Heat

Materials

- 1 candle
- candle holder
- matches

What to Do

This activity should be performed with an adult.

1. Secure the candle in its holder. Take a moment to observe the candle's look and feel for your Observations Report.
2. Light a match and place it close to, but not touching, the side of the candle, about halfway down. Record any changes.
3. Blow out the match and wait several minutes for the candle to cool. Record the look and feel of the candle in the products section of your Observations Report.

Follow-Up Questions

Light the candle wick and allow it to burn for a minute. Then, light a second match. Blow out the candle and immediately place the lighted match about four inches directly above the candle. Bring the match down until the candle burns again.

1. Where was your match positioned when the candle began burning once more? *(1 mark)*

Blow out the candle and allow it to sit for several minutes without burning. Light a third match and place it about four inches directly above the candle. Bring the match down until the candle burns again.

2. Where was your match positioned when the candle began burning again? How does this compare with your observations in question 1? *(2 marks)*

3. When a candle wick is lit, the wax around it melts and eventually heats into a flammable vapour. Knowing this, can you explain any differences between your observations in questions 1 and 2? *(3 marks)*

Option 4: Steel Wool and Vinegar

Materials

- steel wool pad
- vinegar
- small cup
- thermometer
- airtight glass jar (large enough to hold the thermometer)

What to Do

1. Place the thermometer in the jar and close the lid. Wait five minutes and record the temperature on your Observations Report. While you are waiting, take a close look at the steel wool, and write down its properties in your Observations Report.
2. Soak a piece of steel wool in vinegar for one minute.
3. Squeeze the excess vinegar from the steel wool and wrap the steel wool around the bulb of the thermometer.
4. Place the thermometer with steel wool back into the jar and close the lid. Wait five minutes. Record any changes in temperature or to the steel wool itself.

Follow-Up Questions

Soak a piece of steel wool in a cup of vinegar. Leave the mixture in the dish overnight and observe it again the next day.

1. What changes do you notice? Have the properties of the steel wool changed when compared with what you wrote in your Observations Report? *(3 marks)*

2. Have the properties of the vinegar changed overnight, and if they have, how so? *(3 marks)*

LESSON 18: ATOMS AND ELEMENTS REVIEW

Lesson Focus

This lesson contains a review learning activity that you can use to test your knowledge of the concepts within this module.

Learning Activity 2.20: Module 2 Review

You may use your periodic table to help you complete this learning activity.

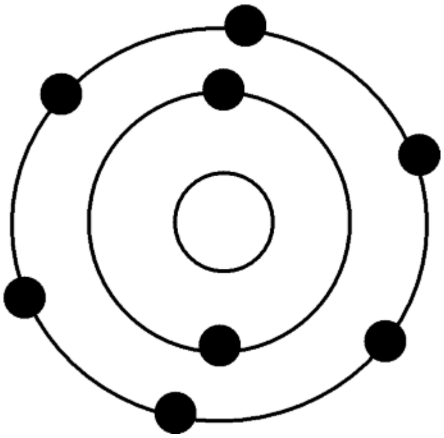
Circle the choice that best matches the question.

1. A neutron
   a. is located in the nucleus of an atom
   b. is a neutral subatomic particle
   c. has a mass of approximately one atomic mass unit
   d. (a) and (b) above
   e. (a), (b), and (c) above
2. An atom has three electrons and four neutrons. Its atomic number is
   a. 7
   b. 4
   c. 3
   d. 1
3. A sample of lead is heated and becomes a liquid. You know a physical change has taken place since
   a. the sample will return to solid lead when it is cooled
   b. a new compound is formed
   c. a precipitate is formed
   d. heat and light are given off as it is heated

continued

Learning Activity 2.20 (continued)

Use the diagram below to answer the following questions.



4. The diagram represents
   a. an atom of oxygen
   b. a molecule of oxygen
   c. a noble gas
   d. an atom of sulphur
5. The person responsible for developing the concept of electrons located as shown in the diagram is
   a. Rutherford
   b. Thomson
   c. Bohr
   d. Einstein
6. Match the names in the left column with the phrases in the right column.

   The historical development of the structure of an atom is an important part of science. Match the name of the scientist with the discovery.

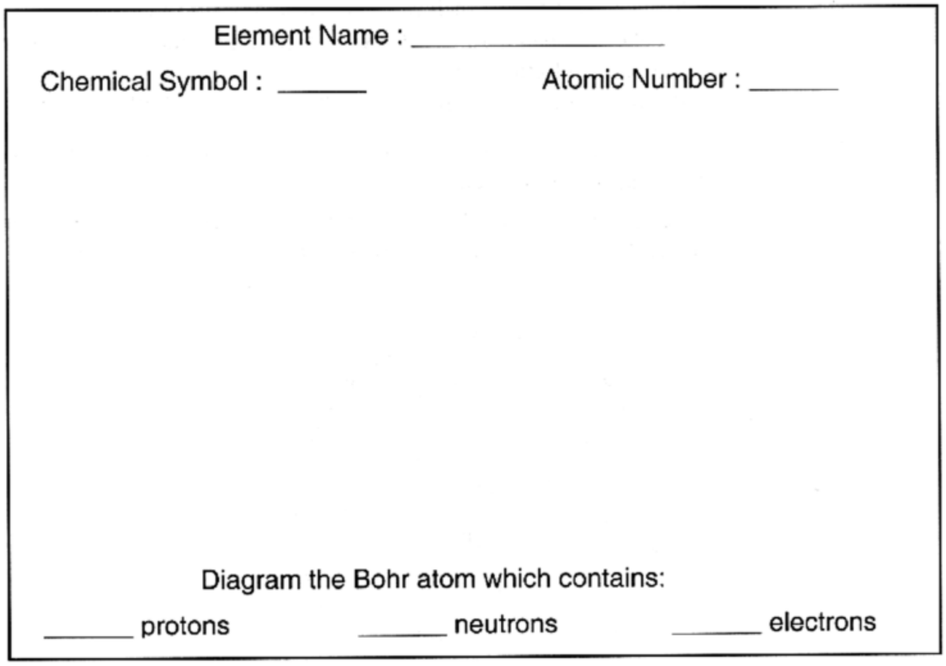
_____ Rutherford	a. developed the atomic theory
_____ Moseley	b. discovered the electron
_____ Empedocles	c. stated that nucleus is a very tiny dense core of the atom
_____ Thomson	d. discovered that electrons circle the nucleus in orbits much like planets circle the sun
_____ Dalton	e. developed the concept of atomic number
_____ Bohr	f. described all matter as composed of earth, air, water, fire

continued

Learning Activity 2.20 (continued)

7. Answer the following:
   a. What element is located on the third period, second family? ________
   b. What name is given to the first family? ____________________________
   c. What family has completely filled electron shells? __________________
   d. What is the atomic number of bromine? ___________________________
   e. To the nearest whole number, what is the atomic mass of fluorine? ______________________________
   f. How many electrons does fluorine have? ___________________________
   g. How many protons does fluorine have? ____________________________
   h. How many neutrons would fluorine have? __________________________
   i. To what family does oxygen belong? ______________________________
   j. Is lithium or beryllium more reactive? _____________________________

8. Complete the form below by filling in the blanks and drawing the Bohr atom for sodium.



Element Name : _________________

Chemical Symbol : ______

Atomic Number : ______

Diagram the Bohr atom which contains:

______ protons

______ neutrons

______ electrons

continued

9. A study of chemistry is made much easier with a periodic table.
   a. Who is given credit for having produced the first periodic table?
   b. What method was used to organize elements in the first periodic table?
   c. What method is used to organize elements in a modern periodic table?

10. All elements in the periodic table are divided into three types.
    a. If one type of element is metals, the other two types are
       i.
       ii.
    b. Malleability is one characteristic of metals. Describe the meaning of malleability.
    c. State three other characteristics of metals.
       i.
       ii.
       iii.

11. Find the elements lithium and chlorine in your periodic table.
    a. When atoms combine to form compounds, there is a gain or loss of electrons in order that the atom achieve noble gas electron configuration. State whether these elements would gain or lose electrons if they were to combine with each other, and indicate the number of electrons gained or lost.
       i. **Lithium**
          Gain or lose (circle one)
          Number gained or lost ______
       ii. **Chlorine**
          Gain or lose (circle one)
          Number gained or lost ______
    b. How does the number of electrons gained or lost affect chemical reactivity?

continued

12. Elements can combine to form compounds through chemical reactions.
    a. Describe how atoms relate to
        i. elements
        ii. compounds
    b. There is one molecule of the compound $NaHCO_3$.
    Write the names of the elements, the symbol, and the number of atoms of each in one molecule of the compound $NaHCO_3$.

Element	Symbol	# of atoms

    c. How many atoms are there, in total, for six molecules of H_3PO_4?
    ____

13. A sample of water is used to dissolve 50 grams of sugar.
    a. Name the solvent. ______________________________
    b. Name the solute. ______________________________

14. Name three indicators that a chemical reaction has taken place.
    a. ____
    b. ____
    c. ____

15. In the list below, a characteristic of an element is described and room is left for the name of the element. You are to fill in the name of the element.
    a. the element used in weather balloons

    ____

    b. the element used to purify water in city water systems

    ____

continued

Learning Activity 2.20 (continued)

c. a liquid element sometimes used in thermometers

____

d. the element most used as an electric conductor

____

e. the element found in period 2, group 13

____

16. State the meaning of the following WHMIS symbol.*

____

17. Read through the following descriptions of a change that takes place in a material. Determine whether a physical or chemical change has taken place and explain your choice.

a. Liquid nitrogen is placed on a flat surface. The nitrogen bubbles and forms a vapour. Eventually, the nitrogen disappears.

Type of change: ______________________________________

Explanation:

b. A student takes a light stick and bends it. Light is given off for a period of time and eventually disappears.

Type of change: ______________________________________

Explanation:

continued

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*Source: *WHMIS Classes, Divisions and Subdivisions and Corresponding Hazard Symbols.* Health Canada 2010. Reproduced with the permission of the Minister of Health, 2011.

Learning Activity 2.20 (continued)

18. Match the terms in the right column with the descriptions in the left column using the letters provided.

_____ diatomic	a. a very small particle with –1 charge
_____ molecule	b. equal to the number of protons and neutrons in the nucleus
_____ mass number	c. a molecule made of two identical atoms
_____ precipitate	d. a family of elements including oxygen
_____ atomic number	e. equal to the number of protons in the nucleus
_____ proton	f. a particle with a +1 charge
_____ chalcogens	g. refers to the repetition of properties found in families of elements
_____ subatomic particle	h. A neutron is an example.
_____ periodicity	i. the smallest particle of a compound
_____ electron	j. sometimes is formed in a chemical reaction

Check the answer key.

Notes

MODULE 2 SUMMARY

Congratulations! You have finished the second module of Grade 9 Science.

Submitting Your Assignments

It is now time for you to submit Assignments 2.1 to 2.4 to the Distance Learning Unit so that you can receive some feedback on how you are doing in this course. Remember that you must submit all the assignments in this course before you can receive your credit.

Make sure you have completed all parts of your Module 2 assignments and organize your material in the following order:

- Module 2 Cover Sheet (found at the end of the course Introduction)
- Assignment 2.1: Atomic Timeline
- Assignment 2.2: Subatomic Particles and the Bohr Model
- Assignment 2.3: Chemical Reactivity on the Periodic Table
- Assignment 2.4: Chemical and Physical Change Experiments

For instructions on submitting your assignments, refer to How to Submit Assignments in the course Introduction.

When you complete all four modules of this course, you will write your final examination. Instructions for arranging to write your final examination and information regarding the final practice examination can be found in the Introduction and at the end of Module 4.

Notes

MODULE 2

Learning Activity Answer Key

MODULE 2
LEARNING ACTIVITY ANSWER KEY

LESSON 2

Learning Activity 2.1: Safety Procedures

1. Complete the following chart to identify the WHMIS symbols* (fill in the blank squares).

Class A

compressed gas

Class D
Division 1

material causing immediate and serious toxic effects

Class D
Division 3

biohazardous infectious material

Class B

flammable and combustible material

Class D
Division 2

material causing other toxic effects

Class E

corrosive material

Class C

oxidizing material

Class F

dangerous reactive material

---

*Source: *WHMIS Classes, Divisions and Subdivisions and Corresponding Hazard Symbols.* Health Canada 2010. Reproduced with the permission of the Minister of Health, 2011.

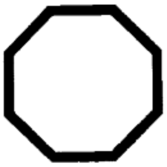
2. Label the following hazardous household product symbols.*

poison

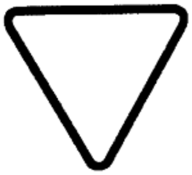
flammable

explosive

corrosive



Contents inside the container are dangerous.



The container is dangerous.

3. Why should you never eat or drink from lab glassware?

   Laboratory glassware may contain poisonous residue.

4.. Why is it unsafe to remove your goggles before the end of a lab period even though you have completed your experiment or investigation?

   Goggles should be worn until the end of a lab period to protect your eyes in the event of an unexpected explosion or spill.

5. From the supplied MSDS on pages 14 and 15 (Figure 2.4), answer the following questions:

   a. What procedure should be used to clean up leaks or spills of sodium hydroxide?

      When spilled (in dry conditions), NaOH can be shovelled up for recovery or disposal. The spill area should be flushed with water and neutralized with diluted acid (vinegar).

   b. What first aid measures should be taken if sodium hydroxide gets in the eyes?

      Wash eyes immediately with plenty of water for no less than 15 minutes (including under the eyelids). If only one eye is injured, keep the injured eye at a lower level to prevent contamination of the uninjured eye.

   c. Is it safe to store sodium hydroxide in a tin container? Why or why not?

      No, sodium hydroxide reacts with tin; therefore, it should not be stored in tin.

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*Source: *Stay Safe – An Education Guide to Hazard Symbols*. Health Canada 2004. Reproduced with the permission of the Minister of Health, 2011.

LESSON 3

Learning Activity 2.2: Science in Ancient Times

1. What is an element according to
   a. Empedocles

      Empedocles stated there are four elements—air, water, fire, and earth.

   b. Boyle

      Boyle stated that an element consists of single unmingled bodies.

   c. Lavoisier

      Lavoisier stated that an element is the final form that can be reached by the breakdown of matter.

2. Describe how Priestley prepared oxygen.

   Priestley prepared oxygen by heating mercuric oxide.

3. Design and describe an experiment to demonstrate that fire is not an element.

   For example, a spoon placed above a candle will become coated with carbon. Fire must contain carbon, so it can't be a pure substance.

LESSON 4

Learning Activity 2.3: The Atom

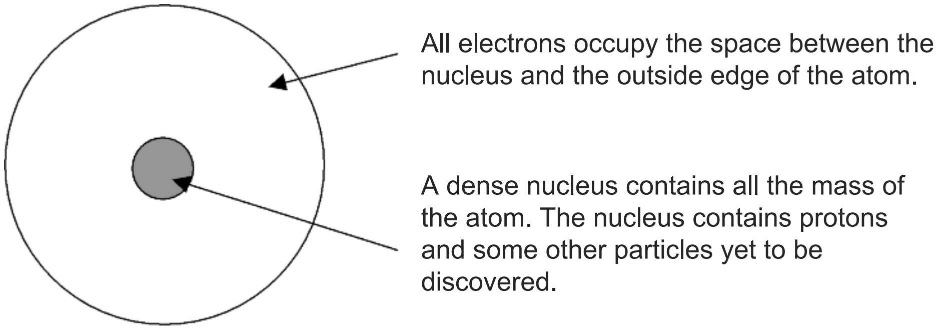
1. State the four main points of Dalton's atomic theory.

   Use your notes for the answer.

2. Describe how Thomson's plum pudding model added to an understanding of the structure of the atom.

   Thomson's plum pudding model indicated that the atom is not one indivisible piece of matter. Thomson showed that an atom must have both positive and negative particles that are smaller than an atom.

3. Describe the atom's structure according to Rutherford's hypothesis. Include a diagram with your description.



   Rutherford demonstrated that an atom is mostly space with a small, dense nucleus at the centre of the atom. Rutherford hypothesized that the nucleus of the atom is positively charged and the negative charges (electrons) are located somewhere around the nucleus in the empty space.

LESSON 5

Learning Activity 2.4: Bohr's Atomic Model

1. How many electrons are able to occupy

   the first orbit? **2**

   the second orbit? **8**

   the third orbit? **8**

2. Describe how the Bohr model advanced understanding of the structure of the atom.

   His work helped to explain the position and behaviour of electrons.

Learning Activity 2.5: Table of Elements and Symbols

3. Respond to each statement by writing the symbol of the element best matching the clue.

Statement	Element Symbol
1. The element used in weather balloons.	**He**
2. The element found in cheaper light bulbs.	**Ne**
3. The element used in water purification.	**Cl**
4. The element used in photographic film.	**Ag**
5. The element used in expensive dental fillings.	**Au**
6. The only common element that is a liquid at room temperature.	**Hg**
7. The element used as sealants in water pipes.	**Pb**
8. The element most used as an electrical conductor.	**Cu**
9. The element once used as an antiseptic	**I**
10. The element used in the production of fertilizers.	**P**
11. The metal element used in electroplating.	**Ni**
12. The element used in pencil leads (not lead).	**C**
13. The element used to absorb heat in spacecrafts.	**Be**
14. The element used in modern batteries.	**Li**
15. The gas element most used in scuba diving air tanks.	**N or O**
16. The element used in the making of steel.	**O**
17. The element used as a fuel component in nuclear reactors.	**U**

LESSON 7

Learning Activity 2.6: Subatomic Particles

	Charge	Location	Mass	Discovered by
Protons	+1	in nucleus	1u	Moseley
Electrons	–1	around nucleus	0	Thomson
Neutrons	0	in nucleus	1u	Chadwick

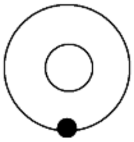
Learning Activity 2.7: Atomic Number

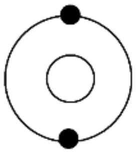
	Iron (Fe)	Krypton (Kr)	Uranium (U)	Sodium (Na)
Atomic Number	26	36	92	11
Number of Protons	26	36	92	11

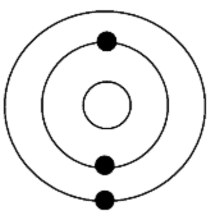
Learning Activity 2.8: Mass Number

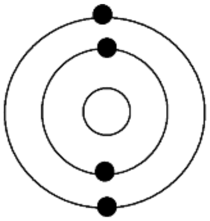
	Lithium (Li)	Chlorine (Cl)	Copper (Cu)	Silver (Ag)
Number of Protons	3	17	29	47
Number of Neutrons	4	18	35	1611
Number of Protons	7	35	64	108

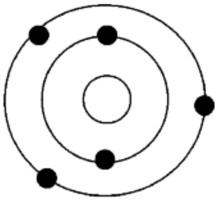
Learning Activity 2.9: The Bohr Model

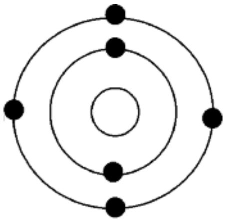

Hydrogen

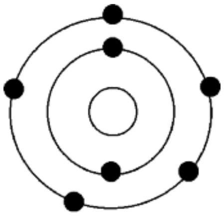

Helium

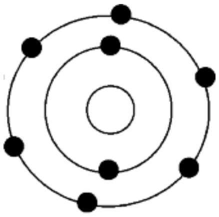

Lithium


Beryllium


Boron


Carbon


Nitrogen


Oxygen

2. Use the atoms you have drawn and arrange the names of the atoms in the table below according to the number of electrons in the outer shell.

	Name of Atom
One Electron in Shell 1	**Hydrogen**
Two Electrons in Shell 1	**Helium**
One Electron in Shell 2	**Lithium**
Two Electrons in Shell 2	**Beryllium**
Three Electrons in Shell 2	**Boron**
Four Electrons in Shell 2	**Carbon**
Five Electrons in Shell 2	**Nitrogen**
Six Electrons in Shell 2	**Oxygen**

LESSON 9

Learning Activity 2.10: Mendeleev’s Periodic Table

1. Use Mendeleev’s table (shown in your lesson) to find an element that is out of position on the basis of atomic mass because similar properties were more important.

   Iodine is out of position on the basis of atomic mass only.

2. a. How were elements in Mendeleev’s periodic table arranged?

      Elements in Mendeleev’s periodic table were arranged according to increasing atomic mass and characteristic properties, but if a problem developed, characteristic properties took priority.

   b. What is Mendeleev’s periodic law?

      Mendeleev’s periodic law states that elements arranged in order of increasing atomic mass will set a pattern in which properties repeat themselves regularly.

3. Explain why Mendeleev included blanks in his periodic table. How did these blank spaces strengthen the belief in his method of organizing the elements?

   Mendeleev included blanks in the periodic table because there were places where known atoms did not fit. He predicted that elements would be found to fill the spaces. Some were found and this reinforced his theory.

4. Why was Mendeleev able to predict the properties of the elements that belonged in the blanks in his table?

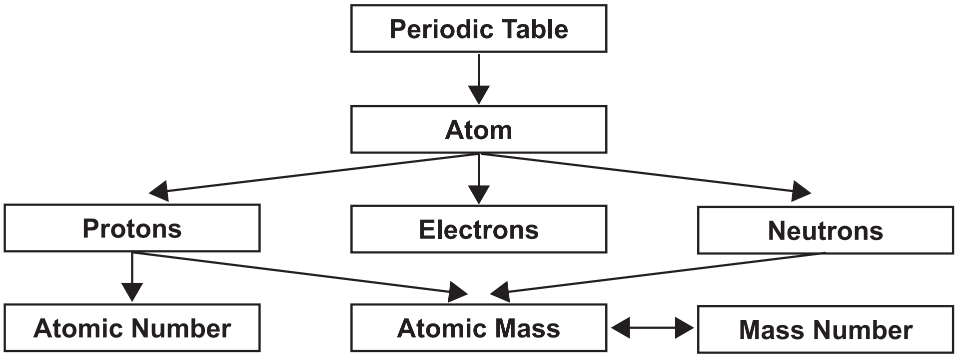
   Mendeleev was able to predict the properties of the missing elements because of the periodic law.

LESSON 10

Learning Activity 2.11: The Periodic Table

1. Construct a concept map that includes
   - periodic table
   - atom
   - electrons
   - protons
   - neutrons
   - atomic number
   - atomic mass

   You may include other words and/or connecting phrases to make your concept map meaningful.



2. Describe where the following are found on the periodic table.
   a. metals

   Metals are located at the left side of the periodic table.

   b. non-metals

   Non-metals are located at the right side of the periodic table.

3. What would happen if fluorine
   a. gained a proton?

   If fluorine gained a proton it would change to neon.

   b. lost a proton?

   If fluorine lost a proton it would change to oxygen.

4. Make a hypothesis about the effect of fluorine's losing an electron. Pay careful attention to the number of protons and electrons in this case.

   If fluorine lost an electron it would have one less negative charge than positive charges. Fluorine would be positively charged.

5. An element has been identified and you know it is an alkali metal.
   a. Predict whether it will be a solid, liquid, or gas at room temperature.

      The new element will be a solid.

   b. Predict the number of electrons in its outer orbit.

      The new element will have one electron in its outer orbit.

   c. Predict its possible atomic number(s).

      The atomic number of the element could be 3, 11, or 19.

   d. Explain the basis of your predictions.

      We base predictions on the periodic nature of elements. The new element should behave as a member of the alkali family.

6. An element has been identified and all you know is that it is a noble gas.
   a. Predict the state of this new noble gas at room temperature.

      The new element will be a gas.

   b. Predict the number of electrons in its outer orbit.

      There will be eight electrons in its outer orbit.

   c. Predict its possible atomic number(s).

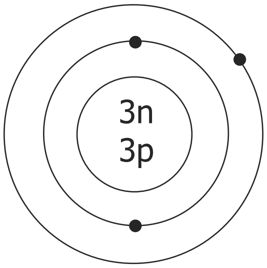
      The possible atomic numbers of the element are 2, 10, 18, and 36.

   d. Explain the basis of your predictions.

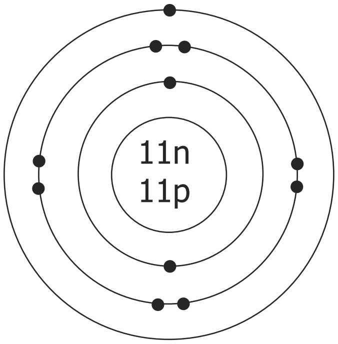
      The predictions are based on the periodic law. The new element will have the same characteristics as other members of the noble gas family.

7. Draw Bohr models for the first two alkali metals, the first two halogens, and the first two noble gases.

Alkali Metals

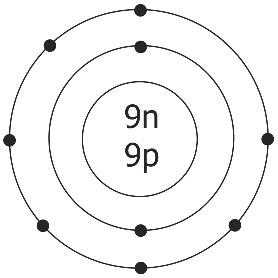


Lithium

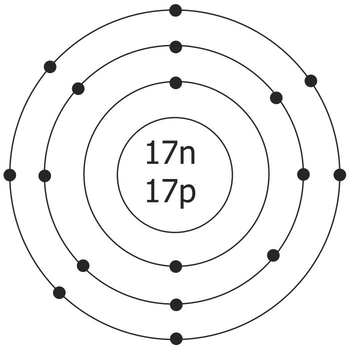


Sodium

Halogens

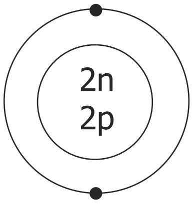


Fluorine

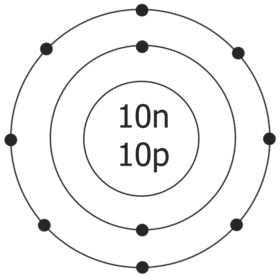


Chlorine

Noble Gases



Helium



Neon

8. Using the periodic table at the end of the lesson, answer the following questions.
    a. How many orbits are there in the elements in the third row (period)?

       Elements in the third row have three shells.

    b. How many orbits are there in the elements in the fourth period?

       Elements in the fourth period have four orbits.

    c. What conclusion can you draw about the periods on the periodic table and the number of orbits the elements have in that period?

       The number of orbits seems to match the period number.

9. Why is hydrogen not considered part of the alkali metals but is seen to be a family of one?

   Hydrogen is considered to be a family of one because it can act like a metal in some reactions and a non-metal in other reactions.

10. a. List the elements along the third period of the periodic table.

       Sodium, Magnesium, Aluminum, Silicon, Phosphorus, Sulfur, Chlorine, Argon

    b. If you were to examine the properties of elements from the left to the right side of a periodic table (a period), how would you describe changes in their
        i. state?

           solid to gas

        ii. atomic number?

            atomic number increases

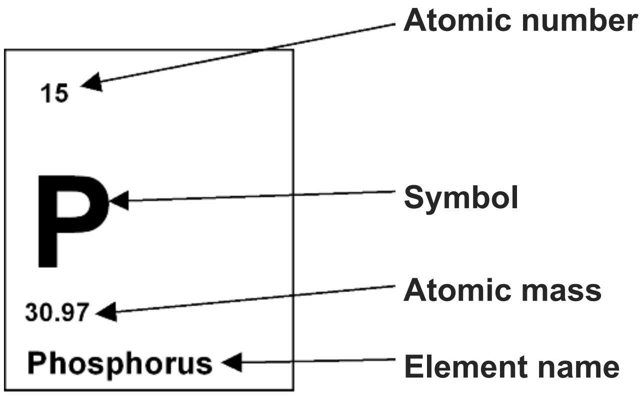
        iii. number of protons?

             number of protons increases

        iv. number of electrons?

            number of electrons increases

11. Identify the facts from the sample element in the periodic table as shown below.



Learning Activity 2.12: Elements, Atoms, and the Periodic Table

1. State the similarities and the differences in Dalton's model of the atom and Bohr's model of the atom (three similarities and three differences).

Similarities	*Differences*
■ All matter is made of atoms.	■ Bohr's model shows atoms are made of subatomic particles.
■ Compounds are formed when elements link together to form a new material.	■ One of the subatomic particles is called an electron.
■ Each element has its own kind of atom.	■ Electrons are located in orbits around the nucleus.

2. Describe briefly how Thomson, Rutherford, Moseley, and Chadwick added to Dalton's model of the atom.

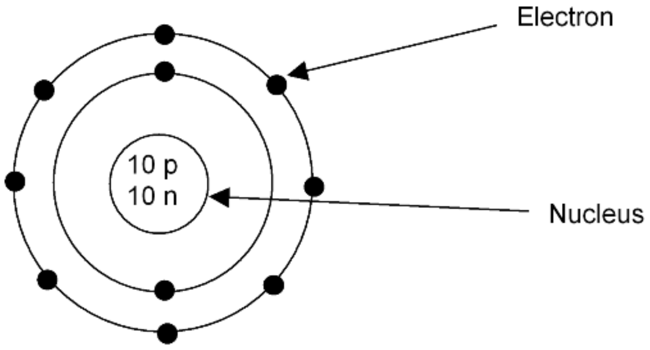
   a. ***Thomson*** **showed the presence of electrons and protons. These subatomic particles are located throughout the atom in what we call the "plum pudding" model.**

   b. ***Rutherford*** **located the presence of a nucleus in the atom. The nucleus is dense and very small compared to the total size of the atom. Positive charges (protons) are located in the nucleus and negative charges (electrons) are located outside the nucleus.**

   c. ***Moseley*** **discovered that protons are located in the nucleus of the atom. He called the number of protons in an atom its atomic number.**

   d. ***Chadwick*** **discovered neutrons in the nucleus.**

3. Draw a Bohr atom for neon and label the nucleus and electrons. Use a periodic table to find information about neon, and label the number of protons and neutrons in the nucleus.



4. Use the terms *atomic number* and/or *mass number* to describe the following:
   a. Number of electrons

      The number of electrons equals the number of protons, which equals the atomic number.

   b. Number of neutrons

      The number of neutrons equals the mass number minus the atomic number.

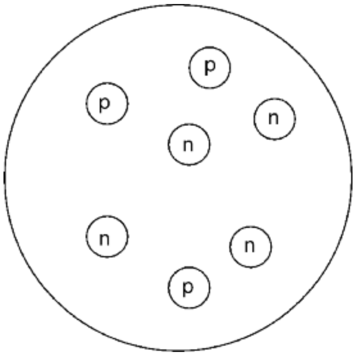
   c. Number of protons

      The number of protons equals the atomic number.

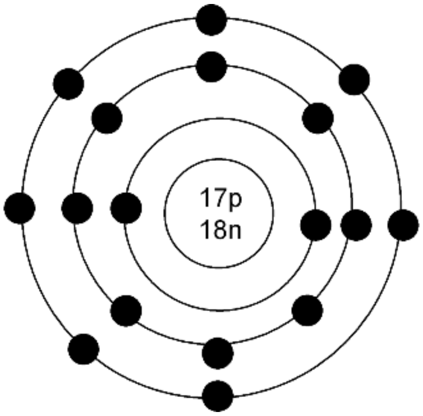
5. You are given the atomic number and the mass number of the five elements shown below. From this information complete the table.

Name	Atomic Number	Mass Number	Symbol	Number of Protons	Number of Neutrons	Number of Electrons
Boron	5	11	**B**	**5**	**6**	**5**
Sulphur	16	32	**S**	**16**	**16**	**16**
Barium	56	137	**Ba**	**56**	**81**	**56**
Gold	79	197	**Au**	**79**	**118**	**79**
Uranium	92	238	**U**	**92**	**146**	**92**

6. Draw the nucleus of lithium. Make a large nucleus so you can draw the protons and neutrons inside it. The atomic number of lithium is three and the mass number is seven.



7. A sample of an element showed that it had an atomic number of 17 and an atomic mass of 35.
   a. Draw a Bohr model of the atom.



   b. What is the name of the element? **Chlorine**
   c. To what family does the element belong? **Halogens**
   d. Is the element reactive? **Yes**
   e. How many electrons does the element need to fill its electron shell? **One**

8. Answer the following questions about the periodic table.
   a. Whom do we give credit for developing the periodic table?

      Mendeleev

   b. How are elements arranged in a modern periodic table?

      Elements are arranged according to atomic number.

   c. What is periodicity?

      Periodicity is the repetition of properties at regular intervals, allowing elements to be grouped in families.

   d. What can be said about the elements that are grouped in columns?

      Elements grouped in columns are called families and demonstrate similar characteristic properties.

   e. What name is given to the elements in columns in a periodic table?

      The columns of elements are called families.

   f. What can be said about the elements grouped in a row in a periodic table?

      Elements in a row show a trend in characteristic properties.

g. What name is given to the row of elements in a periodic table?

   A row is called a period in a periodic table.

h. Why are elements in columns I (1) and VII A (17) so reactive but those in column VIII A (18) are not?

   The elements in column VIII A (18), the noble gases, have their outer shells filled with electrons. They do not require any more electrons for stability, so they are not reactive.

   The elements in column I contain 1 electron in their outer orbits and the elements in column VII need 1 electron in their outer orbits. This makes these elements very reactive.

i. What name is given to column VIII A (18) elements?

   Noble gases

j. How is the periodic table helpful?

   The periodic table allows us to determine properties of elements based on their position in the periodic table.

9. A new element was discovered. The element has one electron in its outer shell.
   a. What family does it belong to? **Alkali metals**
   b. Is it likely to react with water? **Yes**

10. Place true (T) or false (F) beside each of the following statements.
    a. The mass number of an atom is equal to the mass of the protons plus the mass of the electrons. **F**
    b. Most of the atom is empty space. **T**
    c. Most of the mass of an atom is concentrated in the electrons around the nucleus. **F**
    d. Rutherford discovered that about one in 8000 positive bullets would bounce back from the gold foil. **T**
    e. The atomic number plus the number of electrons equals the mass number of an atom. **F**
    f. Aluminum has an atomic number of 13 and a mass number of 27 so it has 14 electrons. **F**
    g. Dalton was right when he said that atoms cannot be divided because atoms are too small to see. **F**

LESSON 11

Learning Activity 2.13: Metals, Non-metals and Metalloids

1. Name three characteristics of
   a. metals

      lustrous, most silver-grey, malleable, ductile, solid (except Hg), conduct heat and electricity

   b. non-metals

      non-lustrous, brittle, insulators (non-conductors) of heat and electricity, either a solid or a gas (except bromine)

   c. metalloids

      solid, lustrous, like non-metals except they conduct electricity, semiconductors

2. You have an object that exhibits the following characteristics:
   - It is a shiny silver colour.
   - It can be shaped into long, thin strips.
   - It is a solid.

   Is this object a metal, non-metal, or metalloid? Explain.

   This object is a metal, as it exhibits characteristics common to metals.

3. You have an object that exhibits the following characteristics:
   - It is breaks easily when hammered.
   - It conducts electricity.
   - It is a solid.

   Is this object a metal, non-metal, or metalloid? Explain.

   This object is a metalloid, as it exhibits characteristics of non-metals except it can conduct electricity.

LESSON 12

Learning Activity 2.14: Chemical Reactivity

1. (½ mark each)

Rating the Reactivity of Chemical Families				
Element	Reactivity	Electrons Gained or Lost	# of Electrons Gained or Lost	Family
Magnesium	**High**	**Lost**	**2**	**alkaline-earth metal**
Nitrogen	**Low**	**Gained**	**3**	**non-metals**
Argon	**None**	**None**	**None**	**noble gases**

2. Determine the following:

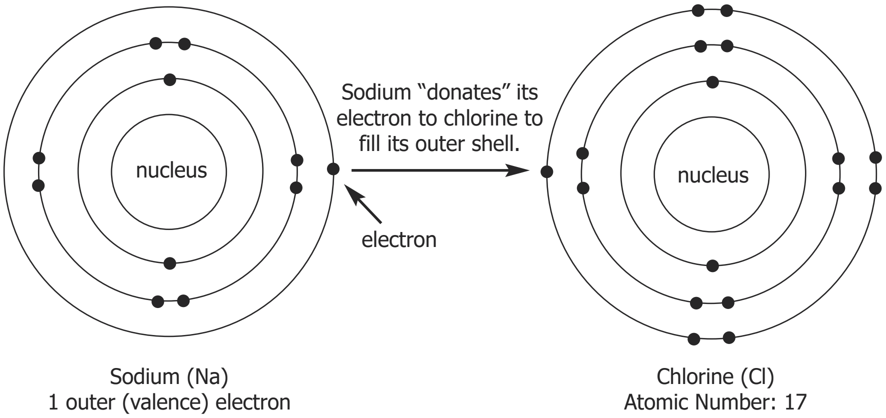
   a. An element has high reactivity and it gains one electron. It belongs to the **halogens** family.

   b. An element has no reactivity. It belongs to the **noble gas** family.

   c. An element has moderate reactivity and it loses 2 electrons. It belongs to the **alkaline-earth metal** family.

3. Using your knowledge of reactivity and electron movement, explain what you think happens when sodium metal and chlorine gas are placed in a container and heated. Draw a Bohr diagram to help explain the result.

   The sodium metal will want to give up an electron and the chlorine gas will want to take an electron. A chemical reaction will take place, and sodium will give its extra electron to chlorine.



A new compound, sodium chloride (NaCl) is formed from heating sodium (Na) and chlorine (Cl).

LESSON 13

Learning Activity 2.15: Compounds

1. Scientists have identified about 10 million pure substances. All these pure substances are formed by 109 elements. Explain how it is possible for so many substances to be formed by such a small number of elements.

   Elements are like letters in the alphabet. Letters in the alphabet can be used to build words; elements can be used to build different substances. All the words in the English language are built from 26 letters in the alphabet; all 10 million substances are built from 109 elements.

2. Try explaining why sodium and chlorine have such different properties when they exist as elements from when they exist as the compound sodium chloride.

   A compound differs from an element since it is a different substance. When sodium and chlorine combine to form sodium chloride, they no longer keep their identity. Sodium and chlorine are joined by an bond that holds them together and changes their properties.

3. Name 10 compounds/chemicals found in your home. These chemicals can be found in everything from food to cleaning products.

   a. baking soda—sodium bicarbonate
   b. salt—sodium chloride
   c. sugar—glucose
   d. cream of tartar—tartaric acid
   e. vinegar—acetic acid
   f. water—hydrogen oxide
   g. cola—carbonic acid
   h. lemon juice—citric acid
   i. aspirin—acetylsalicylic acid
   j. eye drops—tetrahydrozoline chloride

   You don't need to include the chemical name but try it for as many substances as you can. Of course, there are many more chemicals.

4. Distinguish between an
    a. element and a compound

       An element is the simplest form of a material and cannot be broken down into other substances. Compounds can be broken down into simpler substances called atoms.

    b. atom and a molecule

       An atom is the smallest piece of matter. A molecule consists of two or more atoms.

LESSON 14

Learning Activity 2.16: Atoms

$C_6H_{12}O_6$		
Element	Element Name	Atoms
C	**Carbon**	**6**
O	**Oxygen**	**6**
H	**Hydrogen**	**12**

Learning Activity 2.17: Number of Atoms

1.

Table of Atoms Forming Compounds			
Compound	# of Molecules	Element Names	# of Atoms of each Element
$KHCO_3$	1 molecule	**potassium, hydrogen, carbon, oxygen**	**K = 1, H = 1, C = 1, O = 3**
$AlCl_3$	3 molecules	**aluminum, chlorine**	**Al = 3, Cl = 9**
CBr_4	6 molecules	**carbon, bromine**	**C = 6, Br = 24**
H_2SO_4	5 molecules	**hydrogen, sulphur, oxygen**	**H = 10, S = 5, O = 20**
$C_{11}H_{22}O_{12}$	4 molecules	**carbon, hydrogen, oxygen**	**C = 44, H = 88, O = 48**

2. A sample of air is brought into the lab and analyzed (taken apart). The sample was found to contain the following materials. State whether the components are in the form of an atom or a molecule.

	Atom or molecule
a. oxygen (O_2)	**molecule**
b. oxygen (O_3)	**molecule**
c. carbon dioxide (CO_2)	**molecule**
d. carbon monoxide (CO)	**molecule**
e. nitrogen (N_2)	**molecule**
f. argon (Ar)	**atom**
g. methane (CH_4)	**molecule**

3. Why is it important for scientists, who communicate with each other all over the world, to have a uniform set of chemical symbols?

   A uniform set of symbols allows scientists all over the world to use the same set of symbols. This allows communication to take place more effectively.

4. Place the letter for the correct answer in the space at left.

   d simplest form of a pure substance
   c atoms combined in a specific way
   g electrons in the outer electron shell that determine how an atom combines
   f diatomic molecule
   h ozone
   i two or more materials combined to produce a new substance
   b carbon dioxide
   a aluminum
   e is stable since the outer electron shell is filled

   a. Al
   b. CO_2
   c. molecule
   d. atom
   e. He
   f. O_2
   g. valence electron
   h. O_3
   i. compound

5. Chemical Formulas—For each of the molecules in the left column, answer the questions that appear in the other columns.

Chemical Formula	a. How many different kinds of atoms are in this molecule? b. How many atoms of each kind are in this molecule? c. What is the total number of all atoms in this molecule?	Which of the following does this molecule represent?
Na_2O	**a. 2 kinds of atoms** **b. Na=2, O = 1** **c. 3 atoms total**	☑ **a pure substance** ☑ **a compound** ☐ an element ☐ a diatomic molecule ☐ a polytomic molecule
H_2	**a. 1 kind of atom** **b. H = 2** **c. 2 atoms total**	☑ **a pure substance** ☐ a compound ☐ an element ☑ **a diatomic molecule** ☐ a polytomic molecule
Al	**a. 1 kind of atom** **b. Al = 1** **c. 1 atom total**	☑ **a pure substance** ☐ a compound ☑ **an element** ☐ a diatomic molecule ☐ a polytomic molecule
S_8	**a. 1 kind of atom** **b. S = 8** **c. 8 atoms total**	☑ **a pure substance** ☐ a compound ☐ an element ☐ a diatomic molecule ☑ **a polytomic molecule**

LESSON 15

Learning Activity 2.18: Properties of Substances

1. What are the properties of the following substances that make them important for the stated uses?
   a. Diamond is used in drill bits that travel through rock.

      Diamonds are very hard.

   b. Helium is used to fill blimps.

      Density of helium is less than air.

   c. Hydrogen is not used to fill blimps.

      Hydrogen is flammable.

   d. Copper is used in house wiring.

      Copper is a good conductor of electricity.

   e. Some cooking pots have a copper bottom.

      Copper is a good conductor of heat.

   f. Electrical wires are covered in plastic coating.

      Plastic does not conduct electricity, so this protects from electrical shock.

2. Describe what properties were responsible for stopping the use of the following materials. There is a brief report included with each question that will give you information to help answer the question.
   a. PCBs in cooling electric transformers

      PCBs last for a very long time without deteriorating, so they are a long-term environmental hazard. PCBs accumulate in animal and ultimately human fat, where they stay. There are some indications that PCBs can promote certain types of cancer.

   b. Chlorofluorocarbons (CFC4s) in air conditioners

      Chlorofluorocarbons destroy the ozone layer, which protects us from harmful radiation from the sun.

   c. Lead in gasoline

      Lead in gasoline is a serious source of air pollution.

   d. Burning fossil fuels in electric generating plants

      Burning fossil fuels creates acid rain. Acid rain contributes to acidic lakes which kill fish. Acid rain also destroys trees along its path.

LESSON 16

Learning Activity 2.19: Identifying Chemical and Physical Changes

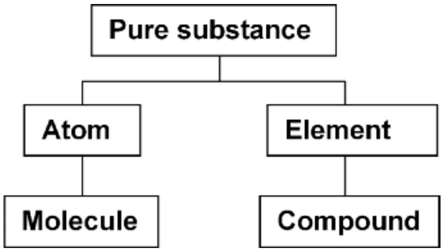
1. The table shown below lists some ordinary occurrences. In the second column, list whether each situation represents a physical or chemical change. In the third column, explain why.

Observed Action	Type of Change	Explanation
a. Water boils out of a kettle or condenses on a cold glass.	**P**	**This action is reversible.**
b. A silver spoon tarnishes.	**C**	**There is a change in colour.**
c. An aluminum pot is put on a burner and gets hot.	**P**	**The change here is physical, as temperature is a physical property.**
d. Dry ice goes from a solid to a gaseous form of carbon dioxide.	**P**	**The change here is physical, as state is a physical property.**
e. An iron rod rusts.	**C**	**There is a change in colour.**
f. Gold melts or solidifies.	**P**	**This is only a change in state.**
g. Sand is mixed in with salt.	**P**	**You can reverse this process and end up with separate sand and salt as when you began.**
h. Methane burns.	**C**	**Both heat and light indicate a chemical change.**
i. A piece of chalk is ground to dust.	**P**	**There has been no change in the chemical composition of the chalk.**
j. An antacid tablet neutralizes stomach acid.	**C**	**Bubbles will form, indicating a chemical reaction.**
k. Glass breaks.	**P**	**There has been no change in the chemical composition of the glass.**
l. Yeast is used to make carbon dioxide in bread and causes it to rise.	**C**	**This change is irreversible.**
m. A lump of sugar dissolves in water.	**P**	**Solubility is a physical property; you can evaporate the water and end up with sugar again.**

2. You are given two white liquids, each in a container. You are told one is milk and one is limewater in which carbon dioxide has bubbled through and formed a precipitate. Describe how you would show which container had the limewater.

   When carbon dioxide is bubbled through limewater, a precipitate is formed. The precipitate will gradually settle out and the liquid becomes clear again. Milk will also turn sour if it is left unrefrigerated overnight.

3. Make a concept map for pure substances using the following terms: *atom, molecule, compound, element*.



MODULE 2

Learning Activity 2.20: Module 2 Review

You may use your periodic table to help you complete this learning activity.

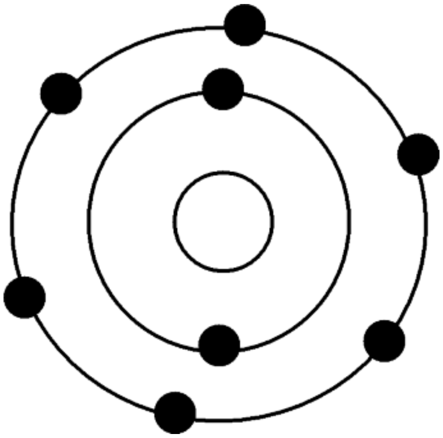
Circle the choice that best matches the question.

1. A neutron
   a. is located in the nucleus of an atom
   b. is a neutral subatomic particle
   c. has a mass of approximately one atomic mass unit
   d. (a) and (b) above
   e. (a), (b), and (c) above

2. An atom has three electrons and four neutrons. Its atomic number is
   a. 7
   b. 4
   c. 3
   d. 1

3. A sample of lead is heated and becomes a liquid. You know a physical change has taken place since
   a. the sample will return to solid lead when it is cooled
   b. a new compound is formed
   c. a precipitate is formed
   d. heat and light are given off as it is heated

Use the diagram below to answer the following questions.



4. The diagram represents
    - **a. an atom of oxygen**
    - b. a molecule of oxygen
    - c. a noble gas
    - d. an atom of sulphur

5. The person responsible for developing the concept of electrons located as shown in the diagram is
    - a. Rutherford
    - b. Thomson
    - **c. Bohr**
    - d. Einstein

6. Match the names in the left column with the phrases in the right column.

    The historical development of the structure of an atom is an important part of science. Match the name of the scientist with the discovery.

    c Rutherford
    e Moseley
    f Empedocles
    b Thomson
    a Dalton
    d Bohr

    a. developed the atomic theory
    b. discovered the electron
    c. stated that the nucleus is a very tiny dense core of the atom
    d. discovered that electrons circle the nucleus in orbits much like planets circle the sun
    e. developed the concept of atomic number
    f. described all matter as composed of earth, air, water, fire

7. Answer the following:
    - a. What element is located on the third period, second family?

      magnesium
    - b. What name is given to the first family?

      alkali metals
    - c. What family has completely filled electron shells?

      noble gases
    - d. What is the atomic number of bromine?

      35
    - e. To the nearest whole number, what is the atomic mass of fluorine?

      19 u

f. How many electrons does fluorine have?

9

g. How many protons does fluorine have?

9

h. How many neutrons would fluorine have?

10

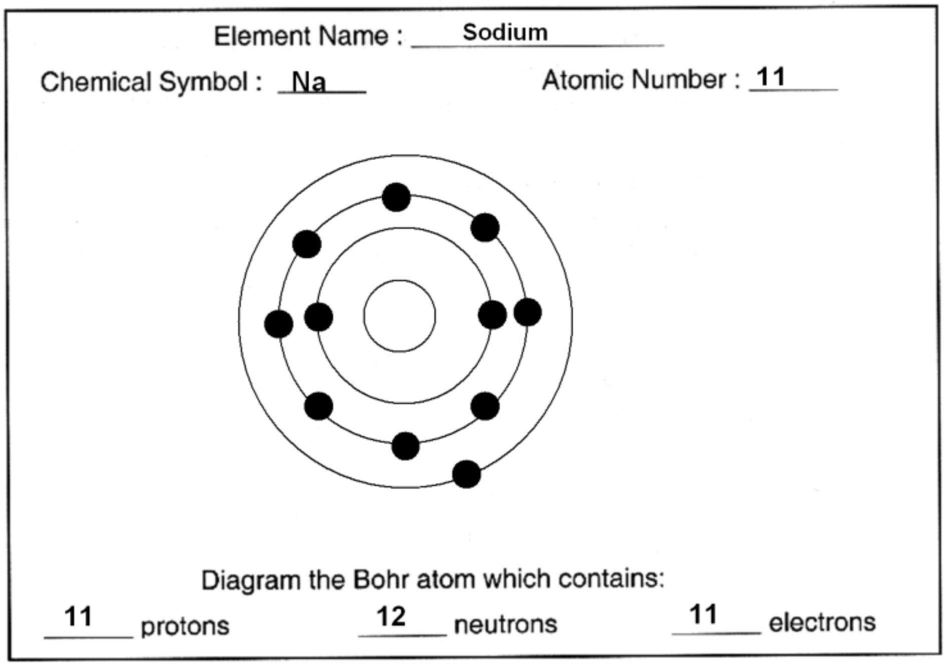
i. To what family does oxygen belong?

chalcogen family

j. Is lithium or beryllium more reactive?

lithium

8. Complete the form below by filling in the blanks and drawing the Bohr atom for sodium.



Element Name : Sodium

Chemical Symbol : Na

Atomic Number : 11

Diagram the Bohr atom which contains:

11 protons

12 neutrons

11 electrons

9. A study of chemistry is made much easier with a periodic table.

a. Who is given credit for having produced the first periodic table?

Mendeleev

b. What method was used to organize elements in the first periodic table?

atomic mass and characteristic properties

c. What method is used to organize elements in a modern periodic table?

atomic number

10. All elements in the periodic table are divided into three types.
    a. If one type of element is metals, the other two types are
        i. non-metals
        ii. metalloids
    b. Malleability is one characteristic of metals. Describe the meaning of malleability.

        Malleability refers to the ability of a some metals to be pounded into thin sheets.

    c. State three other characteristics of metals.
        i. lustre (shiny)
        ii. ductile
        iii. solid (Also: conduct heat, conduct electricity, silver coloured)

11. Find the elements lithium and chlorine in your periodic table.
    a. When atoms combine to form compounds, there is a gain or loss of electrons in order that the atom achieve noble gas electron configuration. State whether these elements would gain or lose electrons if they were to combine with each other, and indicate the number of electrons gained or lost.
        i. **Lithium**
           Gain or **lose** (circle one)
           Number gained or lost __**1**__

        ii. **Chlorine**
           Gain or lose (circle one)
           Number gained or lost __**1**__

    b. How does the number of electrons gained or lost affect chemical reactivity?

        The smaller the number of electrons gained or lost, the greater the chemical reactivity.

12. Elements can combine to form compounds through chemical reactions.
    a. Describe how atoms relate to
        i. elements

           Each element is made of the same kind of atoms only.

        ii. compounds

           A compound is made of one or more types of atoms combining in a specific way.

b. There is one molecule of the compound $NaHCO_3$.

Write the names of the elements, the symbol, and the number of atoms of each in one molecule of the compound $NaHCO_3$.

Element	Symbol	# of atoms
Sodium	**Na**	**1**
Hydrogen	**H**	**1**
Carbon	**C**	**1**
Oxygen	**O**	**3**

c. How many atoms are there, in total, for six molecules of H_3PO_4?

48 atoms

13. A sample of water is used to dissolve 50 grams of sugar.

a. Name the solvent.

water

b. Name the solute.

sugar

14. Name three indicators that a chemical reaction has taken place.

a. A new substance is formed.

b. A precipitate is formed.

c. Heat and/or light is given off. (Also: bubbles are formed, colour changes)

15. In the list below, a characteristic of an element is described and room is left for the name of the element. You are to fill in the name of the element.

a. the element used in weather balloons

Helium

b. the element used to purify water in city water systems

Chlorine

c. a liquid element sometimes used in thermometers

Mercury

d. the element most used as an electric conductor

Copper

e. the element found in period 2, group 13

Boron

16. State the meaning of the following WHMIS symbol.*

The material is flammable.

17. Read through the following descriptions of a change that takes place in a material. Determine whether a physical or chemical change has taken place and explain your choice.

    a. Liquid nitrogen is placed on a flat surface. The nitrogen bubbles and forms a vapour. Eventually, the nitrogen disappears.

    Type of change: **physical change**

    Explanation: **Nitrogen warms up, boils forming a vapour, and disappears as nitrogen gas.**

    b. A student takes a light stick and bends it. Light is given off for a period of time and eventually disappears.

    Type of change: **chemical change**

    Explanation: **Bending the stick allows a chemical reaction to take place. The chemical reaction produces light.**

18. Match the terms in the right column with the descriptions in the left column using the letters provided.

    c diatomic
    i molecule
    b mass number
    j precipitate
    e atomic number
    f proton
    d chalcogens
    h subatomic particle
    g periodicity
    a electron

    a. a very small particle with –1 charge
    b. equal to the number of protons and neutrons in the nucleus
    c. a molecule made of two identical atoms
    d. a family of elements including oxygen
    e. equal to the number of protons in the nucleus
    f. a particle with a +1 charge
    g. refers to the repetition of properties found in families of elements
    h. A neutron is an example.
    i. the smallest particle of a compound
    j. sometimes is formed in a chemical reaction

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*Source: *WHMIS Classes, Divisions and Subdivisions and Corresponding Hazard Symbols.* Health Canada 2010. Reproduced with the permission of the Minister of Health, 2011.

GRADE 9 SCIENCE (10F)

Module 3

The Nature of Electricity

This module contains the following:

MODULE 3
THE NATURE OF ELECTRICITY

Introduction

The conceptual development of the particle model of electricity underlies an understanding of electrostatics and current electricity.

In this module, you will construct simple devices like an electroscope to investigate electrostatic phenomena. A transition from static to current electricity enables you to

- develop a model of electricity
- construct simple devices, like an electroscope, to investigate electrostatic phenomena
- investigate circuits and make connections to daily applications, including the cost of electrical energy and the safety and efficiency of electrical appliances
- investigate hydroelectric power and address sustainability issues associated with the generation and transmission of electricity in Manitoba

You will notice that some of the lessons are accompanied by learning activities and assignments for you to complete. Complete the learning activities to help you learn about the information from the module and check the answer key in order to assess your understanding. Complete the assignments and submit them to the Distance Learning Unit according to the instructions found in the Introduction.

You will also notice that there are times when you are asked to write an answer and to show it to an adult, such as a parent or teacher. Take the time to work carefully in order to develop good habits. Listen to the advice of those whom you have chosen to look at your work. Enjoy this module!

In *Module 3: The Nature of Electricity* you will construct simple apparatuses to explore the meaning of static electricity and current electricity. You will investigate both static and current electricity through exploring, reading, viewing, and applying new information. Connections to daily applications such as electrical safety and cost of electrical energy will be discussed.

Please note that supplies are required for the hands-on experiments found in either learning activities (LA) or assignments (A). In some circumstances, you have a choice of experiments in Module 3: Assignment 3.2, Learning Activity 3.7, and Learning Activity 3.13. **Check these learning activities and this assignment to see which option you would like to do and which materials are required for it. Depending on which options you choose, you will need** ***some*** **of the following materials.**

- Internet access to download *Crocodile Clips* software from www.yenka.com/en/Free_student_home_licences/, which is needed if you choose Option 1 of Learning Activities 3.7, 3.12, and/or 3.13 and/or Assignment 3.5
- plastic straw
- paper bits
- wool cloth/fabric
- transparent tape (packing tape)
- 15 cm of copper tubing (1 cm in diameter)
- 30 cm of string
- pith ball or small piece of foam
- thread
- foam cup
- aluminum foil
- soda can with pull tab
- lemon
- copper wire
- neon bulb, ammeter, galvanometer, or multimeter
- iron nail, plus welding rods, wires, or other metals
- 2 D cell batteries
- 2 small flashlight bulbs
- insulted copper wire
- light gauge wire
- a home hydro bill (a sample bill can be found online at www.hydro.mb.ca/mybill/sample_bill.pdf)

If you have any difficulty obtaining any of the materials required, please contact your tutor/marker.

There are several learning activities placed throughout this module, which will help you practise using the information you will learn. The answer keys for these learning activities are found in *Module 3 Learning Activity Answer Key*. Check the answer key carefully and make corrections to your work.

Assignments in Module 3

When you complete Module 3, you will submit your Module 3 assignments, to the Distance Learning Unit either by mail or electronically through the learning management system (LMS). The staff will forward your work to your tutor/marker.

Lesson	Assignment Number	Assignment Title
2	Assignment 3.1	Understanding Electricity
5	Assignment 3.2	Create Your Own Electroscope
9	Assignment 3.3	Producing Electricity
11	Assignment 3.4	Circuits Review
12	Assignment 3.5	Simple Circuits Lab
15	Assignment 3.6	Electricity Project

Notes

LESSON 1: WHAT IS ELECTRICITY?

Lesson Focus

After completing this lesson, you will be able to

☐ demonstrate that randomly selected materials can be electrified
☐ describe the concept of an electric charge, naming the charges
☐ describe how the two-fluid model could explain electrostatic charge on a material
☐ describe how the one-fluid (Franklin) model could also explain electrostatic charge on a material

Key Words

- two-fluid model
- vitreous electricity
- vesinous electricity
- electrically neutral
- one-fluid model
- positive electrical charge
- negative electrical charge

Introduction

Humans have been aware of electricity since early civilizations; however, our explanation of what electricity is and how it works has progressed through many different models. This first lesson will introduce you to two recent models of electricity, as well as the currently accepted particle model of electricity.

Two-Fluid Model

While the Ancient Greeks knew of static electricity, a proper study was not begun until the 14th and 15th centuries. The existence of two different types of electric charge had been known for some time when French physicist Charles Du Fay began a series of experiments on electricity in the late 1700s.

He discovered that one cork ball touched by an electrified glass rod and a different cork ball touched by an electrified resin rod would attract each other. Du Fay decided there must be two kinds of electric fluids. One of the fluids he called **vitreous electricity** (vitreous is Latin for glass). The other he called **resinous electricity**.

Du Fay began developing a model for electricity. He believed that electricity was a fluid because it seemed to flow under the right conditions from one object to another. An electrically neutral object would have equal amounts of resinous and vitreous fluids.

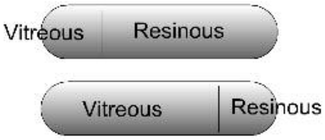
The rod at left has an equal amount of vitreous and resinous fluid. For this reason it is electrically neutral.

An object that was vitreous would have an excess amount of vitreous fluid, but it would still have some resinous fluid. If the object were touched by another object with a resinous charge, there would be a flow of electric fluid from one to the other until a balance was achieved in both objects.

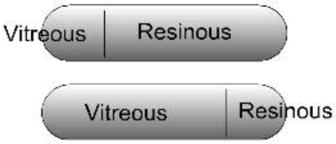
The rod at left has more resinous than vitreous fluid. The object would be called resinous.

The rod at left has more vitreous than resinous fluid and would be called vitreous.

If two objects with equal amounts of extra resinous and vitreous electricity came in contact, both objects would become electrically neutral.



When the two objects are brought together and touch, the fluids travel from one object to the other.



The two objects will share the charge equally when they touch.

One-Fluid Model

In 1752, Benjamin Franklin began studying electricity. He rejected Du Fay’s model of two electrical fluids, stating that there was only one fluid and its electrical nature depended on the excess of or lack of the fluid.

Franklin believed that an object with excess fluid would be attracted to an object with a lack of fluid. The object with the excess fluid would drain into the object which lacked fluid, creating a balance between the two.

Two objects with excess fluid would repel each other because neither object could accept the others’ excess fluid. Similarly, two objects which lacked fluid would not be attracted to each other because neither would be able to give fluid to the other.

Franklin referred to the object with excess fluid as having a positive charge and the object with a lack of fluid as having a negative charge.

Today, scientists have a different understanding about the nature of static electricity (called the particle theory) but they still use the concept of **positive and negative electrical charge**.

The top object is electrically neutral. It is completely filled with electric fluid. This is the object’s natural state.

The second object has a deficiency of electric fluid and is considered to be electrically negative. The electrical fluid is shown inside the irregular line.

The third object has an excess of electric fluid and is considered to be electrically positive. The electrical fluid is shown inside the irregular line that is now larger than the object.

Learning Activity 3.1: Home Experiment

1. Use the KWL (know/want to know/learned) outline below as a part of your ongoing study of static electricity. Complete the first two sections to the best of your ability. Fill in the last section as you continue to learn about static electricity.

   What do you know about static electricity?

What I know:	**What I want to know:**
What I have learned:	

continued

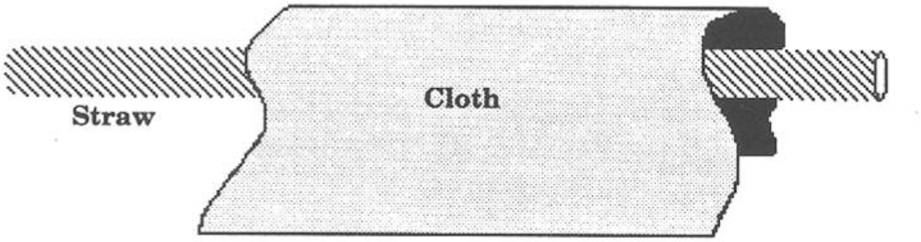
Learning Activity 3.1 (continued)

Follow the instructions for the following activities that can be done at home.

You need these materials:

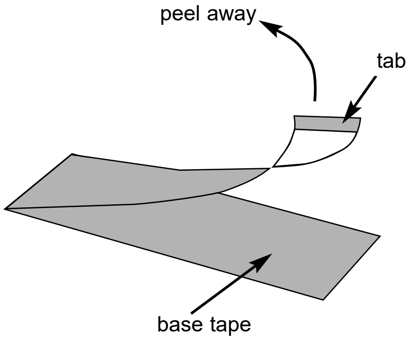
- plastic straw
- paper bits
- wool cloth
- transparent tape (clear packing tape works best)

2. Scatter small pieces of paper on a table. Rub a plastic straw with the wool and bring the straw near the bits of paper. Record what you observed below.



3. Find two materials at home to replace the plastic straw and wool that demonstrate the same effects. Try a toothbrush, pen, or CD jewel case. Rub them with cotton or silk material.

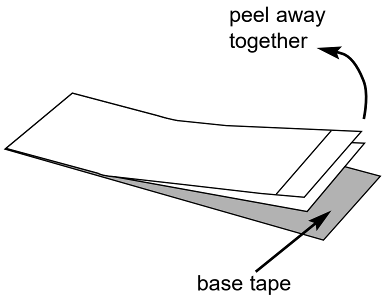
4. Stick a piece of transparent tape about 30 centimetres long on a table (base tape). Take a second piece about 10 centimetres long and make a tab by folding the first centimetre of tape. Stick this tape to the base tape and press it down well with your finger. Now peel the short tape briskly from the base tape. Bring the tape near the paper bits. What can you conclude about the tape?

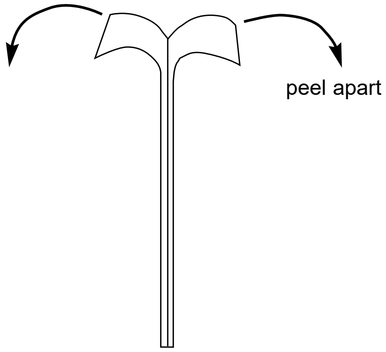


continued

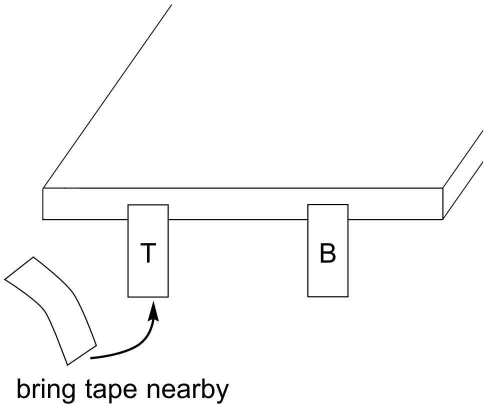
Learning Activity 3.1 (continued)

5. Make another 10-centimetre strip as before. Press them both down on the base tape and then peel them both away together. Peel the tapes from one another. What happens when you bring the tapes near each other?





6. Stick the tapes to the edge of the table, call them tape "T" to indicate the top tape when they are peeled apart, tape "B" to indicate the bottom tape when they are peeled apart. Make another pair of tapes as you did in step 4 and also call them "T" and "B" tapes. Bring each tape, one at a time, near the tapes on the edge of the table. Summarize your results. Include responses to the following in your summary:



   a. What happens to the tapes as you bring them close?

   b. How many different charges can be identified?

   c. Outline a simple rule to describe how different charges affect each other.

7. Now bring each tape near the paper bits.

   a. What happens?

   b. What charge is on the paper bits? Give a reason for your answer.

   c. How do the paper bits affect each other?

continued

Learning Activity 3.1 (continued)

8. Use the two-fluid and one-fluid models to explain the results of the experiment with the cloth and straw. Can these two models adequately explain your observations?

After you have completed the experiments, carefully read the answers to the questions in your answer key. If you need to make any changes to them, do it now. You are in the process of building a model for static electricity. It is important to build the model carefully.

Check the answer key.

Summary

1. Charge is the property of an object, which gives rise to electrical interactions. Two models of electricity were developed between 1770 and 1910.
   - Du Fay’s two-fluid model
   - Franklin’s one-fluid model

   The particle model has existed from 1910 to the present.
2. All three theories seem to be able to explain electrostatic charge on an object.
3. Many different objects can be electrified by rubbing different materials together (e.g., rubbing wool and plastic together produces a negative electrical charge on the plastic).

Notes

LESSON 2: CHARGING BY CONTACT

Lesson Focus

After completing this lesson, you will be able to

☐ identify charges using operational definitions
☐ describe conductors and insulators
☐ name two ways that objects can receive an electric charge
☐ describe how friction can create an electric charge on a material
☐ describe how a material can be charged by contact (conduction)

Key Words

- operational definition
- pith ball
- repulsion
- conductors
- insulators
- neutral
- net charge
- positively charged
- negatively charged
- charge transfer
- conduction
- particle model

Introduction

During the home experiment in Lesson 1, you experimented with some materials at home in order to test some properties of static electricity. The following could be a summary of your findings:

1. Many different materials can be **electrified** by rubbing (friction).
2. An object can be **charged** by rubbing, and **charge** gives rise to forces of attraction and repulsion.
3. Given the observations of attraction and repulsion, we can say two kinds of charge exist.
4. Charges that are like (that is, created in similar circumstances) **repel**, and charges which are unlike **attract**.
5. A neutral object is attracted to both the positive and the negative charges.
6. Three models can explain the existence of two types of electrostatic charge:
    - **Two-fluid model**

      A neutral object has equal amounts of each fluid. A charged object has more of one or the other.
    - **One-fluid model**

      A neutral object has a natural amount of electric fluid. A charged object has either too much or too little fluid. This is Ben Franklin's model.
    - **Particle model**

      There are two kinds of particles: positive and negative. A charged object has more of one or the other.

Positive and Negative Charges

Scientists accepted the particle model of electric charge as experiments in the early parts of the twentieth century began to reveal more information about the nature of charge and matter.

Later, you will explore more completely how the particle model works. At this point you are going to experiment with charged rods and paper bits.

An electrostatic charge has already been described as being either positive or negative. But what does positive mean? What does negative mean? Sometimes it is necessary to describe concepts on the basis of the behaviour of objects. When you do this, the concept is described using an operational definition. What is an **operational definition** of a positive or negative charge?

- An object is considered to have a positive charge when it is repelled by a glass rod that has been rubbed with silk.
- An object is considered to have a negative charge when it is repelled by a plastic straw rubbed with wool.

For the purposes of this module, you will be experimenting with static electricity. For many of the experiments, it is useful to have a lightweight, neutral object to test. A **pith ball** is a lightweight, neutral piece of coated Styrofoam that is used by science teachers to help with their static electricity experiments. At home, you can use a small piece of paper or a small piece of Styrofoam instead. When describing experiments in this module, the terms pith ball, paper bit, and Styrofoam bit will all be used to refer to the lightweight neutral object.

Notice that the operational definitions are both based on **repulsion**, the ability to repel. Because neutral objects can be attracted to both positive and negative charges, **attraction** is not used in an operational definition.

Two types of material are identified based on how well they transmit electric charge. One type of materials allows the electric charge to pass through easily. These substances are called **conductors**. The other materials do not easily allow the electric charge to pass through. These materials are called **insulators**.

Note

Good electrical conductors are copper, silver, and aluminum. Metals generally are conductors, but some are better than others. Insulators are generally non-metals. Some good insulators are rubber, most plastics, and glass.

Objects can exist in three electrical states. An object can be **neutral**, in which case the positive and negative charges on the object are balanced (the **net charge** is zero). An object can be **positively charged**, which means that there are more positive charges on the object than negative (the **net charge** is positive). This excess of positive charge is due to a deficiency (lack) of negative charge. If the object is **negatively charged**, it means that there are more negative charges than positive on the object (the **net charge** is negative).

It is impossible to diagram accurately charge distribution on any reasonable scale. In a material, millions and millions of charges are present. In diagrams, only a few charges are shown that indicate the **net charge**.

Charging by Rubbing

You have observed objects that can be charged by rubbing. A plastic straw or a piece of vinyl rubbed with wool receives an electric charge. A glass rod rubbed with silk or a piece of vinyl rubbed with cotton creates a different charge.

The plastic straw or the vinyl rubbed with wool has negative charges because they repel a negatively charged object. Glass rubbed with silk and vinyl rubbed with cotton have positive charges because they repel a positively charged object.

The particle model for electric charge states that the plastic straw must have more negative charges than positive charges when rubbed with wool.

Certain materials such as wool and vinyl and some materials such as glass and synthetics contain negative particles that are loosely held. When these substances are rubbed by another material, they are able to give away negatively charged particles. A piece of wool is able to give away negative charges to the plastic straw, leaving the wool positively charged and the straw negatively charged. When plastic is rubbed with cotton, the cotton will remove negative charges from the plastic, leaving the plastic positively charged and the cotton negatively charged.

Learning Activity 3.2: Charging by Friction

1. Why is it dangerous to golf during a thunderstorm?
2. When wool rubs a plastic straw, where do the extra negative charges on the plastic straw come from?

   The particle model also states that the piece of plastic must have more positive charges than negative charges when rubbed with cotton. The particle model for electric charge states that only negative charges move in solids.
3. Explain how the glass rod could receive a positive charge.
4. Would the glass tubing attract or repel the paper bits?

Check the answer key.

Remember that plastic, vinyl, glass, rubber, and acetate are all insulators. This means the charge produced on the objects does not travel anywhere but remains at the spot where it is rubbed by a cloth. As a result, the objects have localized charges that do not move. This means you can hold the objects without them losing the electric charge.

You can test the model by rubbing a balloon in your hair. See if the balloon will hold the charge when you hold it in your hand.

Charging Using Charge Transfer

You have seen that electric charge can be moved from one object to another by rubbing. The **particle model** explains how this transfer takes place.

Electric charge can travel from one object to another in two ways:

- One way is when two different materials come in contact and are removed. When a plastic straw is rubbed with wool and then the two materials are separated, a charge is left on both materials. The rubbing is useful in that it provides as much contact as possible between the wool and plastic. You have experienced the results of different materials in contact producing an electric charge when you placed one piece of tape on another and then removed the top tape. The top of one tape is one material and the bottom of the other (the sticky side) is a different material. The two pieces of tape stick together forming a good contact between the two.
- The other way is by touching a charged object and another, usually neutral, object. The charge moves between the charged object and the neutral object. This method of **charge transfer** takes place by contact or **conduction**.

When a charge is transferred by conduction there must be contact between the charged object and the object becoming charged.

Learning Activity 3.3: Charging by Conduction

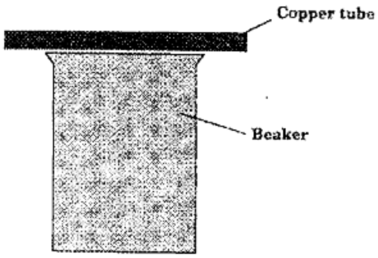
A learning partner may help you in this learning activity.

You will need the following materials to complete this learning activity:

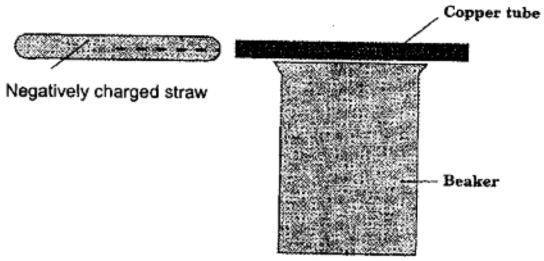
- plastic straw
- 15 cm of copper tubing (1 cm in diameter)
- beaker or drinking glass
- transparent tape (packing tape)
- wool cloth or fabric
- pith ball or small piece of foam
- 30 cm of string

In this learning activity, you will set up a simple device for transferring electric charge by contact. You will then charge a plastic straw and observe how it reacts with neutrally charged objects. Be sure to answer the question that follows.

Step 1: Place a piece of 1-centimetre copper tubing that is about 15 centimetres long on a beaker or a drinking glass. If you use a drinking glass, tape the copper tubing to the top of the glass so it will not roll off. The copper tube can be a piece of copper plumbing.



Step 2: Bring a negatively charged plastic straw (has been rubbed with wool) up to the copper rod and touch it. Rub the plastic on the copper tube to release as much charge as possible to the copper tube. Remember, the plastic straw is not a conductor and the charge remains on it. You can also charge the plastic straw several times and deposit more charge on the copper tube.



Step 3: Tie a 30-centimetre string to a pith ball (or small piece of foam). Charge the foam bit by touching it with the charged plastic straw. Hold the end of the string and bring the foam bit close to the copper tubing.

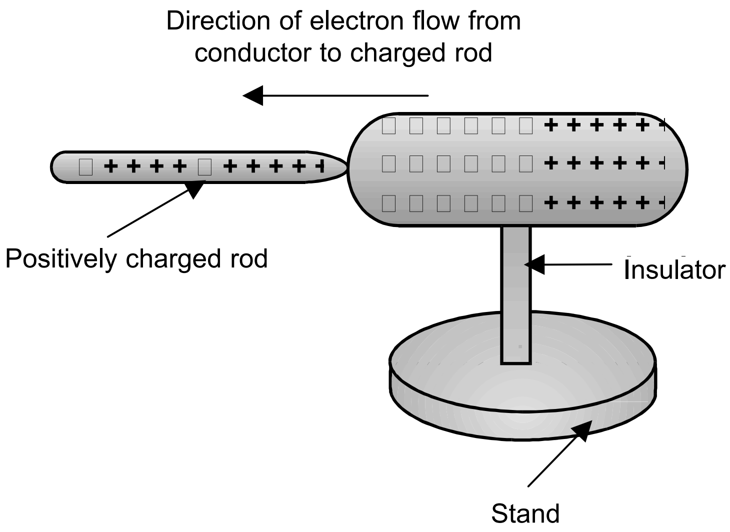
1. Draw a diagram to show what happened when the foam bit approached the copper tubing. Be sure to indicate the electrical charge on each object.

Check the answer key.

You can see from the learning activity that a charge has been transferred to the copper tube. Why does a charge transfer occur? To answer the question, we need to know that the best condition for electric charge exists when there are equal numbers of positive and negative charges on an object. If there is an excess of negative charges, they will repel each other and try to leave the object; if there is an excess of positive charges, they will attract negative charges from another source. In all situations, there is an attempt to reach a neutral condition where the number of positive and negative charges on an object are equal.

Charging by Conduction (Contact)

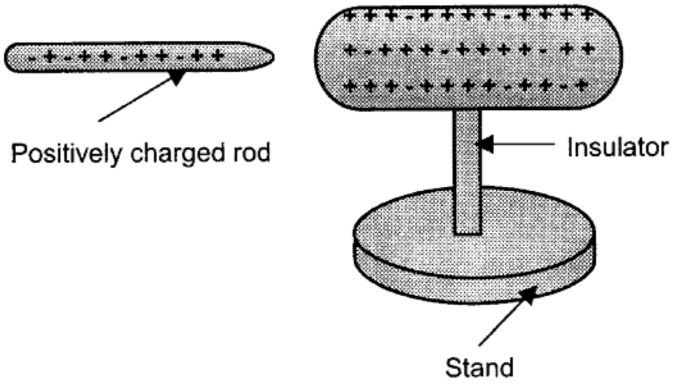
A charge can be transferred from a charged rod to a conductor by bringing the rod in contact with the conductor. There is no need to ground the conductor in this case because the charge will go directly from the charged rod to the conductor or vice versa.



As the charged rod approaches the conductor, the electrons in the conductor move as shown in the diagram. When the rod touches the conductor, as is the case in the diagram, the positive rod attracts the electrons in the conductor. After the rod is removed, the rod has a positive charge that is less than it was and the conductor also has a positive charge. The positive charge on the rod is reduced because the transferred electrons would have neutralized some of the positive charge. The charge on the conductor is positive because some of the electrons in the conductor have moved to the rod, leaving a net positive charge.

When the charged rod touches the conductor, electrons are attracted to the charged rod. As electrons move to the charged rod, they cancel out the positive charge on the rod. As a result, the charge on the rod diminishes as it receives electrons from the conductor. The conductor, on the other hand, has an increasing positive charge as it loses electrons to the charged rod. As the rod's attraction to electrons diminishes and the conductor's attraction to electrons increases, there comes a point where both the charged rod and the conductor exert equal attraction for the electrons and the movement of electrons stops. This transfer takes place instantaneously.

Note the reduced positive charge on the charged rod.



Notice the charge on the rod and the charge left on the conductor are the same.

Review: The Particle Model for Electricity

The behaviour of objects when they receive an electrostatic charge by friction or by charge transfer can be explained using the **particle model**.

- An important concept in the model is that *only negative particles can move when solids are charged electrostatically*. When a plastic straw is rubbed with wool, the wool gives some of its negative particles to the plastic straw to make it negatively charged. The negative charge occurs because there is an excess of negative particles on the plastic straw. The wool would then have fewer negative particles than positive and have a positive charge.
- There is no movement of positive charges in either the wool or the plastic straw. *Charge occurs because of negative particle movement from the wool to the plastic straw and the resulting excess or lack of negative particles compared to the number of positive particles.*
- The plastic straw receives the negative particles from the wool on its surface. The negative particles will not move anywhere because plastic is an insulator. The negative particles stay where the plastic straw has been rubbed with the wool. The plastic straw can have a charge at one point but not another depending on where the wool rubbed the plastic straw.
- When the plastic straw touches the copper tube, negative particles will travel from the straw to the copper tube if the plastic straw is charged at the point where the contact is made. To make certain a reasonable charge transfer has taken place, rotate and move the plastic straw as it makes contact with the copper tube.
- *Negative particles move from the plastic straw to the copper tube because they are repelled by the extra negative particles on the plastic straw*. This transfer continues and the negative particles continue to build up on the copper tube until the negative particles repel each other with equal force on both the plastic straw and the copper tube. The negative charges exist on the plastic straw in the first place as a result of rubbing the straw with the wool.
- Once negative particle transfer has stopped there are excess negative particles on both the plastic straw and the copper tube (i.e., **both objects have the same charge**).
- A positively charged rod operates in much the same way. Only negative particles move, but they move from the copper tube to the positively charged rod to leave a deficiency of negative particles (positive charge) on the copper tube. The positively charged rod would still have a positive charge since it and the copper tube attract electrons with the same force when a new charge distribution has finished.

Summary: The Particle Model of Electricity

1. Charge is a particle that is conserved. It may not be created or destroyed.
2. There are two kinds of charge: positive and negative.
3. Neutral objects have equal numbers of positive and negative charges.
4. Positive charges are fixed and negative charges are free to move.
5. A negatively charged object has a greater number of negative charges than positive; a positively charged object has a smaller number of negative charges than positive.
6. Objects can be charged by contact (conduction) between them when
    - two dissimilar materials come in contact with each other and are then separated
    - a charged object touches a neutral or differently charged object
7. Charge can be shared by contact. Materials that allow charges to move easily are called conductors. Materials in which charges do not move easily are called insulators.
8. Like charges repel and unlike charges attract.

Notes

Assignment 3.1: Understanding Electricity (12 marks)

1. Explain how you would positively charge a neutral glass rod. *(1 mark)*

2. How could you show that the glass rod was positively charged? *(2 marks)*

3. As you brought the positively charged rod near (and eventually touched) a neutral foam ball, what would you expect to happen? Explain using diagrams. *(6 marks)*

4. Define in your own words the following terms: negative charge, neutral charge, and positive charge. (3 marks)

LESSON 3: ELECTRON MODEL AND ATOMIC STRUCTURE

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe how the structure of an atom is the basis of the electron theory of electrostatic charge
- ☐ explain the principle of charge separation
- ☐ summarize the assumptions of the electron model
- ☐ describe how the electron model can explain charging an object by conduction
- ☐ use the electron model to explain the process of grounding

Key Words

- subatomic particles
- electron
- nucleus
- proton
- electrostatically neutral
- conductor
- insulator
- grounded

Introduction

In this lesson, you will learn about how the structure of the atom has an impact on our understanding of static electricity. It goes deeper into some of the concepts we have already learned in this module. Depending on the order in which you completed this course, you may already know some of the information presented here. *Module 2: Atoms and Elements* goes into more detail about the structure of the atom and subatomic particles.

Electron Theory

Scientists made important discoveries about the structure of the atom in the late 1800s and the early 1900s. Initially, it seemed the atom was one single particle that could not be divided further, but further experimenting showed that there were **subatomic particles**. Subatomic particles make up the atom. They include protons, neutrons, and electrons.

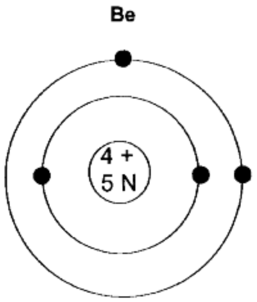
Sir Joseph John Thomson discovered electrons using an apparatus similar to a modern TV tube. The **electron** was found to be very small, have very little mass, and be negatively charged.

Ernest Rutherford found a small dense central part of the atom (the **nucleus**) where the positive charge was concentrated. Rutherford later demonstrated that the nucleus contained small, positively charged objects called **protons**. A proton has the same amount of charge as an electron but is opposite to the electron (or positive). The proton is approximately 2000 times as dense as an electron.

Atoms ordinarily contain the same number of electrons and protons. The equal numbers of positive and negative charges in the atom mean that it is **electrostatically neutral**.

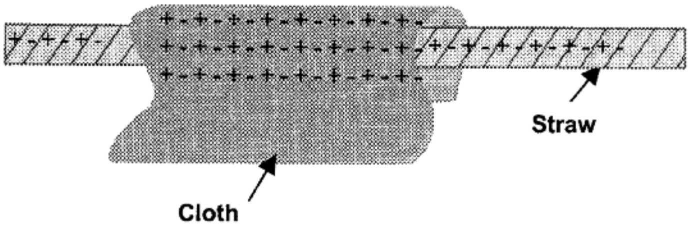
This is a good place to review the structure of an atom using the Bohr model. A Bohr model for the Beryllium atom is shown below. See Module 2 for more information about Bohr models.

The diagram helps to show that there are strong forces that hold the protons in the nucleus. Electrons, on the other hand, are more loosely held and travel around the nucleus, so they are more easily removed. If an atom gains an electric charge, it is because it either gains or loses electrons. Protons will not move from the nucleus.

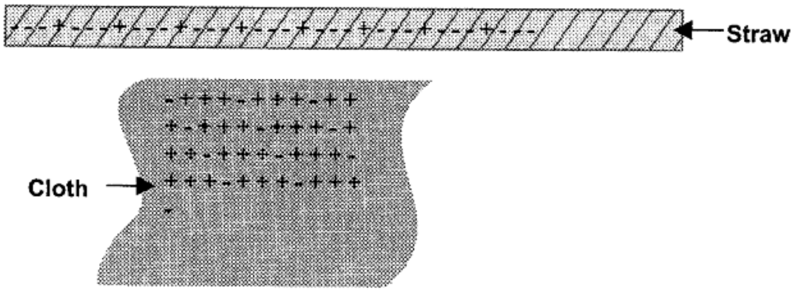


If an electron is added to the atom, it now contains one more electron than protons and has a net negative charge. If an electron is removed, it now has one less electron than protons and has a net positive charge. The negative and positive charges result from the addition or removal of electrons only.

Electrons are so easily transferred to or from some atoms that contact between two different materials will cause the transfer to take place. For this reason, you rub a plastic straw with wool (rubbing helps improve contact) to create an electrostatic charge in the straw. The wool transfers electrons to the plastic straw and it becomes negatively charged. The wool, because it has lost electrons, becomes positively charged.



Before the wool cloth rubs the plastic straw, both the cloth and the straw are neutral. As you can see from the diagram, they have equal numbers of positive and negative charges that cancel each other out, leaving the cloth and straw with a zero net charge.



Once the cloth rubs the straw, there is an excess of electrons on the straw and a lack of electrons on the cloth. As a result, the straw is negatively charged and the cloth is positively charged.

Conductors and Insulators

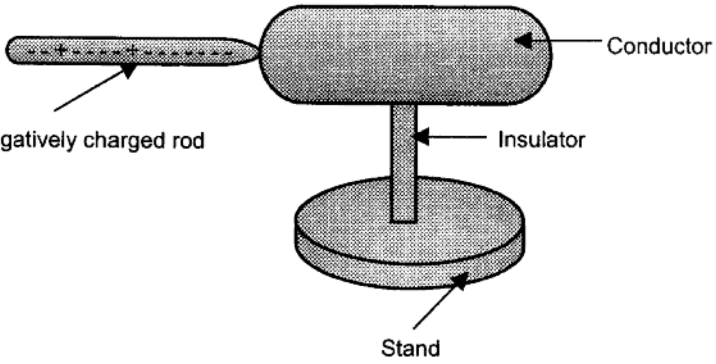
Conductors, such as metals, have electrons that are not attached to any particular nucleus. This means the electrons can easily move from one nuclear region to another. If there is either a force of attraction or repulsion on the electrons, they easily move one direction or another in a conductor.

Insulators, such as glass and plastics, have electrons that are more strongly attracted to the nucleus of the atom. As a result, electrons are not easily moved from one nucleus to another. Instead they tend to remain associated with one nucleus (i.e., one place on the insulator).

You produce a charge on an insulator by rubbing it with cloth or fur, which gives off electrons, and then placing the insulator in your hand. The charge is not lost because the insulator holds the electrons in place. The electrons will not flow into your hand and neutralize the insulator unless your hand touches a charged spot. If your hand touches a charged spot on the rod or straw, only that spot will be grounded. **Grounding** is a method of distributing charge; to be grounded is to become electrically neutral. All the other spots remain charged. A conductor cannot be charged this way because all the charge drains away through the hand no matter how the conductor is held.

Learning Activity 3.4: Electron Model of Electricity

1. What kind of charge is on an object that has an excess of electrons?
2. If an object loses electrons, what is the charge on the object?
3. What can be said about the number of positive and negative charges on a neutral object?
4. Explain your answer in question 3.
5. Why is it that electrons always move and protons do not when a solid object is charged?
6. Why would it be a waste of time to hold a copper tube in your hand and try to charge it by rubbing it with a cloth?
7. a. What charge will move in the apparatus below?
   b. What direction will the charge move in the apparatus below?



continued

Learning Activity 3.4 (continued)

c. After the charged rod is removed from contact with the conductor, what is the charge left on
    i. the conductor?
    ii. the rod?

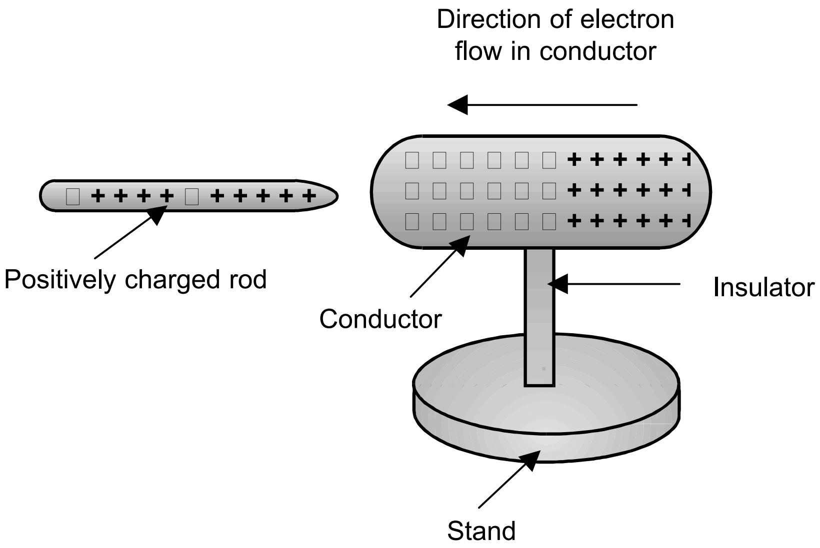
d. What name is given to this method of charging an object?

8. A cotton cloth is used to create a charge on a piece of acetate.
    a. What charge is left on the acetate?
    b. What is the charge left on the cotton cloth?
    c. Explain your answers to parts (a) and (b) above.

9. Describe the process of charging by contact.

10. a. What makes a material a good conductor?
    b. What makes a material a good insulator?

11. Using the electron model, explain what is happening in the following diagram at a subatomic level.



Check the answer key.

Summary

- The particle model of electricity (model of electric charge) can be referred to as the electron model since we now understand the structure of atoms and the behaviour of electrons. Atoms are made of subatomic particles called protons, which are stationary, and electrons, which are able to move in some materials (conductors).
- When an object is charged by rubbing, one material removes loosely held electrons from the other material. As a result, one becomes negatively charged and the other positively charged.
- The electron model explains the behaviour of conductors and insulators.
- The electron model can explain charge transfer by conduction. Once again, only electrons move.
- A charged conductor can be grounded by providing a path for electrons to travel either from the conductor to the ground or from the ground to the conductor.

LESSON 4: TESTING THE MODEL

Lesson Focus

After completing this lesson, you will be able to

☐ describe what is meant by a discrepant event
☐ demonstrate how the electron model explains a discrepant event
☐ explain, using the electron model, the behaviour of a pith ball placed between two oppositely charged plates
☐ describe how liquid and gas solutions allow both positive and negative charges to move

Key Words

- discrepant event
- operational definitions
- aqueous solution
- ions

What Is a Discrepant Event?

Occasionally, something happens that is unexpected. Imagine that you are holding a ball in your hand. You release the ball and it flies upward; that is a **discrepant event**. A discrepant event is sometimes contrary to predictions; it often surprises, startles, puzzles, or astonishes the observer. On the basis of experience, you predict the ball will fall downward, so its falling upward would be unusual and would catch you by surprise.

In science, occasionally a discrepant event challenges an existing model. The lab activity described below is just such a case.

Learning Activity 3.5: Static Electricity Model

A learning partner may help you in this learning activity.

You will need the following materials to complete this learning activity:

- small piece of paper
- thread
- plastic straw
- wool cloth/fabric

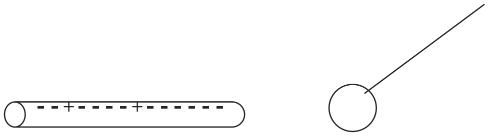
Hang a neutral paper bit by a thread. Charge a plastic straw by rubbing it with fur or wool and bring it close to the paper bit.

1. Describe what happens as the charged plastic straw is brought close to the paper bit.
2. Describe what happens after the charged straw touches the paper bit.
3. Explain why this activity demonstrates a discrepant event.

The following diagrams show the steps you just observed as the paper bit approaches the charged plastic straw. Describe the movement of electrons in each of the diagrams.

Draw any charges on the paper bit, and use an arrow to show the direction of electron movement.

4.



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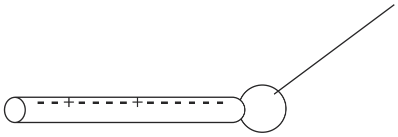

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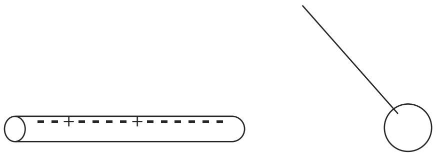

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Learning Activity 3.5 (continued)

7. Is the electron model for electrostatics able to explain the behaviour of the neutral paper bit when it touches the charged plastic straw?

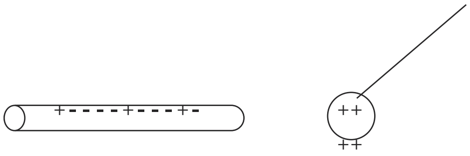
Check the answer key.

When using **operational definitions** for positive and negative charges, you may remember that they were based on repulsion. The two definitions are stated again below.

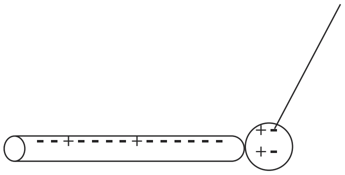
- An object is considered to have a positive charge when it is repelled by a glass rod that has been rubbed with silk.
- An object is considered to have a negative charge when a vinyl strip that has been rubbed with wool repels it.

Why use repulsion rather than attraction as part of the operational definition?

You have just observed the answer to the question. Notice that the negatively charged straw attracted the neutral paper bit. The operational definition of a positive charge based on its being attracted to a negatively charged straw is invalid because a neutral object is also attracted to a negatively charged straw.



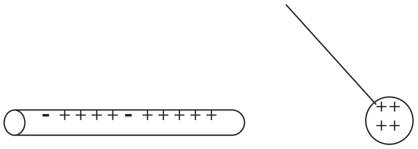
Positively charged paper bit (or pith ball) attracted to the negatively charged straw.



Neutral paper bit (or pith ball) attracted to the negatively charged straw.

Attraction cannot be used to identify a charge because neutral objects are also attracted.

Repulsion occurs when a positive charge comes close to a glass rod rubbed with silk, so it is a valid definition of a positive charge.

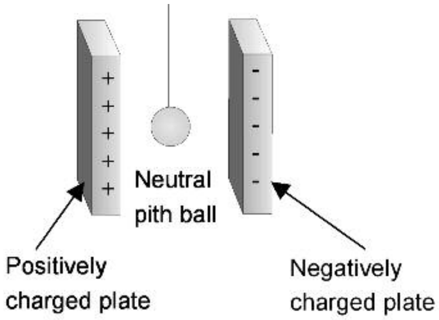


Only a positively charged paper bit (or pith ball) is repelled by a positively charged straw.

Repulsion also occurs when a negative charge comes close to a plastic straw rubbed with wool, so it is a valid definition of a negative charge.

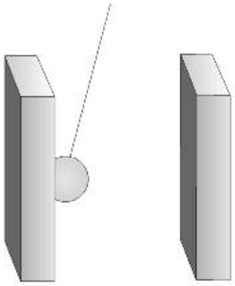
Learning Activity 3.5 (continued)

8. The three diagrams below show the movement of a neutral pith ball when it is placed between two plates with opposite charges. In this scenario, the pith ball has been placed slightly closer to the positively charged plate on the left. Explain the motion of the pith ball using full sentences. The first diagram has been completed for you.

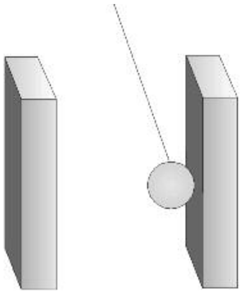


The pith ball is placed between the two plates, slightly closer to the positive plate. There is no motion yet.

a.



b.



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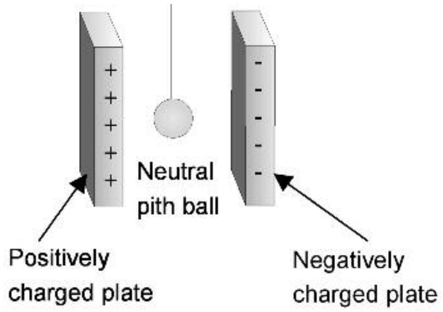
Learning Activity 3.5 (continued)

c.

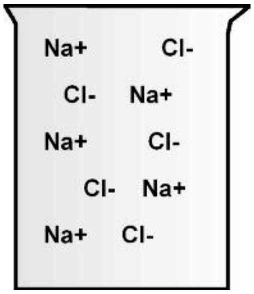


d. Why will the pith ball eventually stop moving?

Check the answer key.

Electric Charges in Solutions

First, it is possible to create a solution that is liquid or gas. A liquid or **aqueous solution** is formed when a solid is dissolved in a liquid. Some solids, when dissolved in a liquid, form charged particles in solution. For example, table salt (NaCl) dissolved in water creates an aqueous solution with positively (Na+) and negatively (Cl–) charged particles in it. The charged particles are called **ions**.



In the solution at left, the positive and negative particles are both able to move. If the negative charges move to the left, the positive charges would then move to the right.

A gaseous solution with charged particles can also be created. A high-energy source, such as X-rays, can be passed through the gaseous solution. Some of the molecules of gas will be hit by the X-ray and absorb energy. As a result, there can be enough energy to force an electron off a gas atom, leaving it as a positive ion. The positive gas ion and negative electron can travel in both directions just as the positive and negative charges do in aqueous solutions.

So far in this course, there has been little attention given to movement of charge in aqueous and gaseous solutions because they are less common. They do exist, however, and are an important part of any study of electricity.

Whenever the movement of charges has been discussed in electrostatics up to this point, it has been carefully stated that only negative charges (electrons) move in solids.

Learning Activity 3.5 (continued)

9. What happens when there are charged particles in a solution?
10. Revisit the KWL you completed in Learning Activity 3.1: Home Experiment. Add anything new you have learned about electricity.

Check the answer key.

Summary

- Models are used to help us understand the behaviour of materials. As we learn more about materials, the model will change. As scientists learned more about the structure of matter, the model for charge on a particle changed from Du Fay's two-fluid and Franklin's one-fluid models to the particle (electron) model we use today.
- Anomalies and discrepant events are much the same. Perhaps they differ only in that an anomaly occurs as part of an experiment, whereas a discrepant event is something that happens to anyone who has a set of expectations that aren't met. In any case, a model must explain both anomalies and discrepant events or it needs to be changed.
- The particle (electron) model can explain each case shown in this lesson.

LESSON 5: THE ELECTROSCOPE

Lesson Focus

After completing this lesson, you will be able to

- ☐ make your own electroscope to detect an electric charge on an object
- ☐ use your electroscope to detect the type of charge on an object
- ☐ use your electroscope to get some idea about the size of charge on an object
- ☐ use your electroscope to charge an object by conduction and induction
- ☐ describe how an electroscope operates using the particle model in electrostatics

Key Words

- electroscope

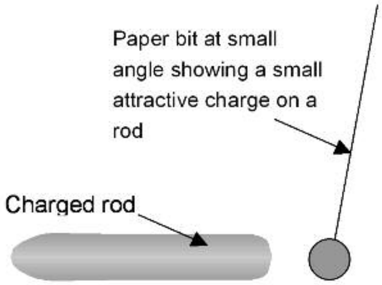
As scientists began exploring the mysteries of electricity, they developed many devices to help them. One of these devices—the electroscope—is studied in this lesson in some detail. The electroscope will help you understand how scientists worked and allow you to test the electron model for electrostatics.

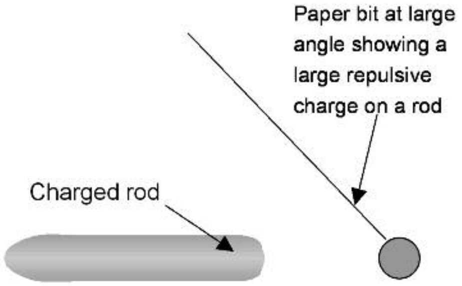
Electroscope

An electroscope functions as a tool for determining whether or not an electrical charge is present in an object. You have already used a paper bit to find out if a charge is present on an object in some experiments. In these cases, the paper bit acted as an electroscope.

An electroscope is able to perform three kinds of measurement to

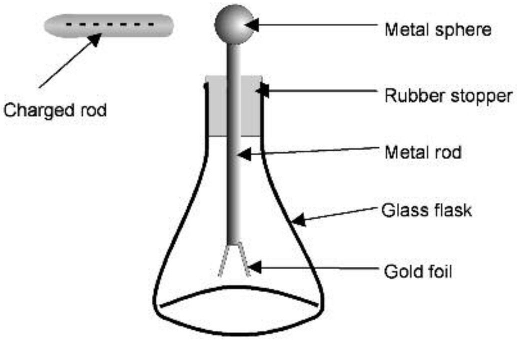
- detect the presence of an electrostatic charge on an object
- determine the type of charge on an object
- determine the amount of charge on an object (e.g., if you bring a paper bit close to an object and the paper bit moves at a large angle with the string, the object has a greater charge than if the paper bit makes just a small angle)





The paper bit is a simple electroscope. There are other electroscopes that are more sophisticated. A gold leaf electroscope is an example of an electroscope developed by scientists in the 1700s.

Gold Leaf Electroscope



Notice the charged rod has only negative charges shown. From now on, only the net or residual charge will be shown on charged objects.

Use the particle model to explain the operation of the gold foil electroscope.

Answer the following questions assuming that a negatively charged rod is allowed to touch the metal sphere at the top of the electroscope.

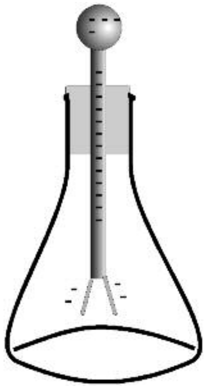
Learning Activity 3.6: The Electroscope

1. What happens to the negative charges on the rod as it touches the metal sphere?
2. The negatively charged rod is removed. What is the charge remaining on the rod?
3. After the rod is removed, what is the charge left on the electroscope?
4. Show the charge distribution on the electroscope by drawing the charges on the diagram on the previous page (electroscope diagram). Draw only the excess charge that is left when the charged rod is removed.
5. Why does the charge not travel into the rubber stopper and the glass flask?
6. What is the charge on the
   a. left gold foil?
   b. right gold foil?
7. What will happen to the two pieces of gold foil as a result of the charges on them?
8. Gold foil can be hammered into extremely thin sheets. This makes the sheets of foil very light. Explain why the lightness of the foil is important in an electroscope.
9. How could you neutralize the electroscope so the two pieces of gold foil will go back to their original position?
10. The negatively charged rod is brought close to the metal sphere on the electroscope, but you do not allow it to actually touch.
    a. Describe the movement of charges in the electroscope.
    b. What happens when the charged rod is removed?

Check the answer key.

Determining the Type of Charge on a Rod

The second function of an electroscope is to determine the kind of charge on an object. The diagram below shows an electroscope that has been negatively charged.



The electroscope shown at left has been given a negative charge.

Measuring Quantity of Charge

The electroscope has limited use as a device to measure the amount of charge on an object. The diagrams at the beginning of the lesson show the paper bit being pushed away by a charged rod. We can use the diagrams to conclude the greater the distance between the paper bit and the charged rod, the greater the force of repulsion between the paper bit and the charged rod.

The greater force of repulsion between the rod and paper bit is caused by a larger electrostatic charge on the rod. A gold foil electroscope behaves much the same way. A larger charge on the rod causes greater movement of the gold foil leaves. Electroscopes do not provide any method for measuring a number value for the amount of the charge (this measurement will be covered in a more advanced course).

Summary

- The electroscope has the following functions:
  - detecting the presence of an electric charge on an object
  - determining the kind of charge on an object
  - estimating the size of the charge on an object
- A paper bit can function as an electroscope, but there are also leaf and vane electroscopes.

Assignment 3.2: Create Your Own Electroscope (22 marks)

A learning partner may help you in this assignment.

For this assignment, select one of the two electroscopes shown below, and make one.

You will need the following materials to complete this learning activity:

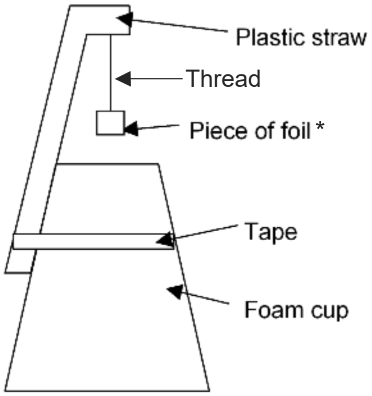
Option 1

- plastic straw
- thread
- piece of light weight aluminum foil
- tape
- foam cup

Option 2

- soda can with pull tab
- piece of light weight aluminum foil
- foam cup
- tape

Option 1.

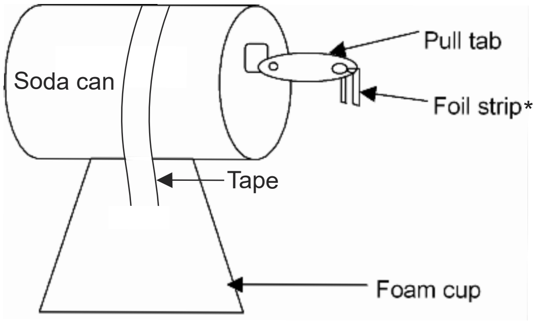


This electroscope behaves like a paper bit. The piece of foil will either move toward or away from the charged rod.

---

* Be sure to use very light weight aluminum foil.

Option 2.



This diagram shows how you can construct a leaf electroscope out of easy-to-find materials.

---

* Be sure to use very light weight aluminum foil.

Which electroscope model did you make?

____

1. Describe how you can test for the following: *(6 marks)*
   a. the presence of an electric charge on an object *(2 marks)*

   ____

   ____

   ____

   b. the kind of charge on an object *(2 marks)*

   ____

   ____

   ____

   c. the size of a charge on an object *(2 marks)*

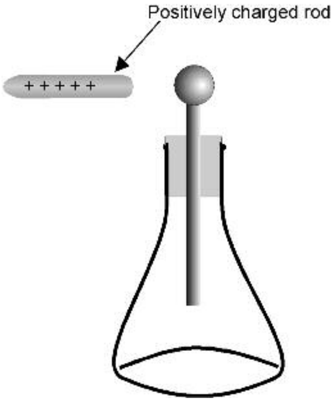
   ____

   ____

   ____

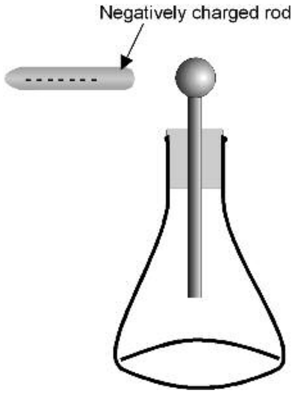
2. Test your electroscope with items from around your house. List five items in your house that have a static electric charge, and describe the evidence that a charge exists. *(6 marks)*

3. Draw the position of the gold foil leaves in the diagram at the right to demonstrate how the electroscope detects the type of charge on the rod. Also show the charge on the leaves. Keep in mind the electroscope is negatively charged initially. *(2 marks)*



4. Draw the position of the gold foil leaves in the diagram at the left. Also show the charge on the leaves. Keep in mind the electroscope is negatively charged initially.

   Use the electron theory to explain the behaviour of the leaves. *(4 marks)*



5. Summarize how a negatively charged electroscope can be used to determine if a nearby object has a positive or negative charge. *(2 marks)*

   ____

   ____

   ____

6. Describe how the electroscope would behave if it were initially charged positive. *(2 marks)*

   ____

   ____

LESSON 6: ELECTRIC CELL

Lesson Focus

After completing this lesson, you will be able to

☐ construct an electric cell

Key Words

- Volta cell
- voltaic cell
- electric current
- dry cell
- wet cell
- ammeter
- galvanometer

Introduction

You have been learning about static electricity and the role that protons and electrons play in the distribution of charges. You may be wondering what about lights, computers, and MP3 players? What type of electricity do they use? In the next few lessons you will be learning about current electricity and applying what you learn to electric circuits.

Electric Cell—Beginnings

In 1794, Luigi Galvani made a remarkable discovery. Galvani, a medical doctor with an interest in the relationship between muscles and static electricity, used an electric machine to create a spark. When the spark touched frog legs, they jumped and twitched. To test, as Franklin believed, whether lightning was also electricity, Galvani took the frog legs outside. He used brass hooks to hold the frog's legs but the legs rested against an iron railing. Galvani observed the legs twitching when there was lightning, but he also noticed the legs continued twitching when the lightning stopped. It was obvious that the legs twitched when electricity went through them, but Galvani was observing a discrepant event.

What remained unclear to Galvani was the reason the legs moved when the lightning stopped. Galvani decided that there must be another kind of electricity called animal electricity that caused the legs to twitch on their own. Galvani published his findings, which Alessandro Volta read with interest.

Volta discovered that two different metals placed in a salt or acidic solution created the same effect on the frog's legs as the **electric machine** (i.e., a frog leg connected to either the electric machine or the two metals in a salt solution caused the frog leg to twitch). The two different metals placed in a salt or acidic solution became known as a **Volta cell** or a **voltaic cell**. The Volta cell is described in more detail below.

Volta also noted the Volta cell would give off sparks continually without being recharged. Volta concluded that the cell must be able to provide a continuous supply of electrons to the wire. This almost never-ending supply of electrons is called an **electric current**.

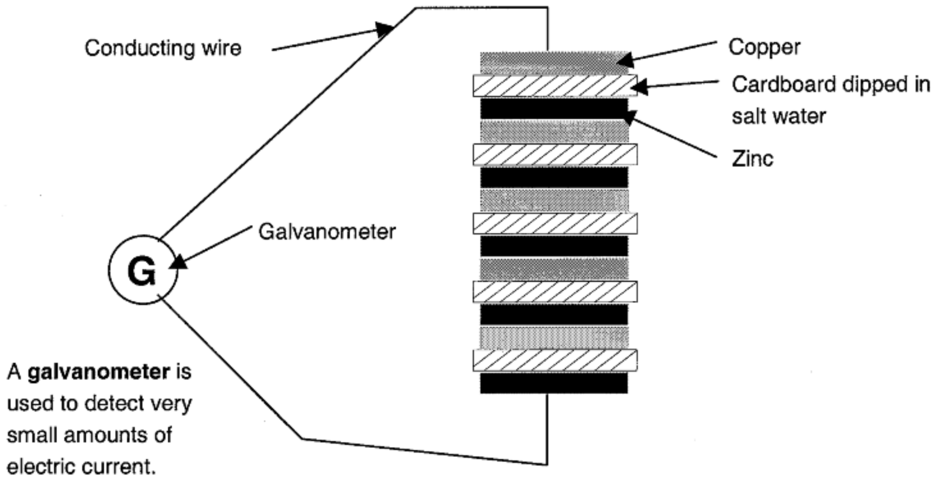
Volta also showed conclusively that there is only one kind of electricity, and that organic electricity and inorganic electricity are really the same thing. The frog's legs twitched only because of the application of electricity from an outside source. What Galvani observed was an electric cell formed by the liquids in the frog's legs and the two dissimilar metals: brass and iron. The unusual electric cell produced enough electricity to cause the frog's legs to twitch.

The supply of electrons does eventually come to an end, as anyone using a **dry cell** (a cell that contains a paste rather than a liquid) knows, but to Volta, who had known only static electricity and its very brief spurts of electrons, this was a never-ending supply indeed!

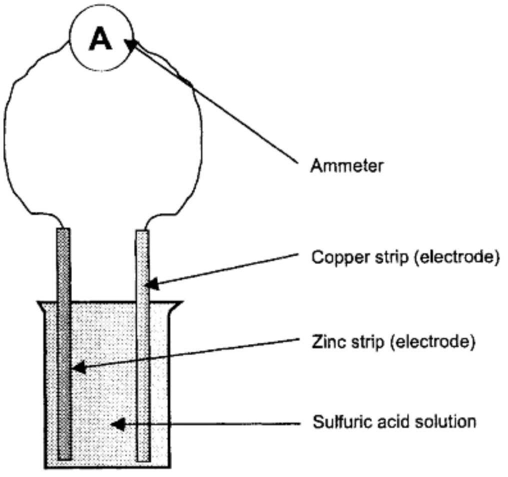
Volta Cell

Volta's electric cell produced a continuous supply of electrons when connected to a conductor. The electric cell consisted of two different metals in a salt or acid solution. A chemical reaction takes place resulting in a supply of electrons. Eventually, the chemical reaction slows down and stops. When the chemical reaction stops, the supply of electrons stops and the cell is "dead."

Volta created a cell or Volta pile by alternating layers of discs made of copper, cardboard dipped in salt water, and zinc. Volta used many different combinations of metals and solutions but the ones shown below are considered typical.



Volta's cell soon became known as the voltaic cell. The **voltaic cell** is called a **wet cell** because a liquid (aqueous solution) surrounds the two types of metals or electrodes. An ordinary lab voltaic cell has been constructed by students for many years and is shown below. Voltaic cells do not have any practical use today as they have been replaced by dry cells.



Note

Ammeters and galvanometers are instruments use to detect and measure electric current. An **ammeter** is used to measure larger currents than a **galvanometer** can handle.

Learning Activity 3.7: The Voltaic Cell

This learning activity offers you two choices for experimenting with voltaic cells. Read over Options 1 and 2, and choose one learning activity to complete. When you have finished the learning activity, answer Questions 1 to 5.

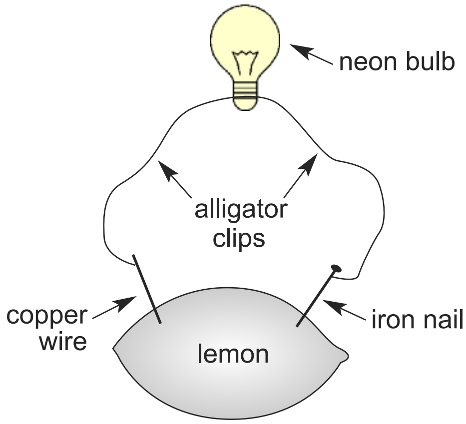
A learning partner may help you in this learning activity.

Option 1

You will need the following materials for Option 1:

- lemon
- copper wire
- iron nail
- neon bulb, ammeter, galvanometer, or multimeter
- metal nails, welding rods, wires, or other metals

A simple, reliable voltaic cell can be made from a lemon. Stick a piece of copper wire in one part of the lemon and an iron nail in another part, as shown in the diagram.



Try different metals in the lemon. Use different kinds of nails, welding rods, wires, or any other metals. Make a chart to show which combinations produce an electric current.

You can detect an electric current using the neon bulb. You can also detect an electric current using a tool called an ammeter or a galvanometer. These tools are usually found in a school. If you can use one of these current detectors from a school, ask a teacher to show you how to use it. Another current-detecting tool is called a multimeter. A multimeter can be used to detect not only electric current, but other *parts* of an electric circuit. If you know someone who has a multimeter, ask him/her if you can use it and ask for instructions at the same time. To make a meaningful chart, it is important for you to know the names of the metals in this investigation.

continued

Learning Activity 3.7 (continued)

If you do not have access to the needed materials for Option 1, you may try Option 2.

Option 2

The computer software *Crocodile Clips*, available at www.yenka.com/en/Free_student_home_licences/, can create models of voltaic cells (also known as *circuits*).

1. Open the *Crocodile Clips* software program on your computer.
2. Select "create a circuit."
3. Select and drag a light and a 1.5 V battery into the workspace.
4. Click on the end of a post coming out of the battery and attach it to a post on the light.
5. Click on the other battery post and attach it to the light.
6. Does the light turn on?

Questions

1. What can you say about lemon juice that would explain the production of electricity when copper and zinc are placed in the lemon?
2. Volta noted that in electrostatics, charges move momentarily and then quickly come to rest, but in an electric circuit using a voltaic cell, charges continue to move for a long time. Describe how you could test Volta's statement to see if it is correct.
3. What are the main parts of any voltaic cell?
4. How does the voltaic pile demonstrate the main parts of the cell?
5. Describe how the conditions in which Galvani saw frog legs twitch satisfied the requirements for a voltaic cell.

Check the answer key.

Summary

- Galvani noticed that frog legs moved when iron and brass metals touched them. Galvani thought he had observed a different form of electricity that was resident in the frog's legs. He described this as animal electricity.
- Volta experimented with various materials to show that electricity is the same regardless of the source.
- Volta made the Volta pile using layers of two different metals surrounded by discs soaked in a salt or acidic solution.
- Voltaic or wet cells became common sources of current electricity for many years. Today, dry cells are a source of portable current electricity. Hydroelectricity is also a source of household electricity.
- The basic requirements of a wet or dry cell are two different metals surrounded by an acid, salt, or base.

LESSON 7: ELECTRIC CURRENT

Lesson Focus

After completing this lesson, you will be able to

☐ describe electric current in terms of random motion, drift current, and rate of flow

☐ define electric current in terms of rate of flow

☐ define coulomb and relate it to electric current

☐ calculate electric current in a circuit knowing the number of coulombs passing a section of conductor over a period of time

Key Words

- metallic conductors
- electrolytic solutions
- electrode
- random movement
- drift velocity
- voltaic cell
- electrolyte
- ammeter
- dry cell
- open circuit
- closed circuit
- coulomb
- ampere

Introduction to Electric Current

Pause for a moment and think about the things that you do each day that require electricity. Imagine that electricity did not exist—how would your life be different?

An electric current is electrons moving through a conductor at a certain rate when there is something pushing them. Electrons can be pushed through a conductor by

- using a charged rod or simple static electric machine in electrostatics
- using a voltaic/dry cell or some current generator

In either case, electrons move from one place to another. Electron movement is usually brief in electrostatics because of the small amount of electric charge available in the charged object. A voltaic cell takes much longer to discharge; as a result, electron movement takes place over a longer period of time.

The movement of electrons (e.g., electric current) requires further investigation. An electric current is found in many different devices, including

- metallic conductors such as copper wire
- vacuum diodes found in some electronics equipment
- platinum electrodes found in electrolysis apparatus
- gas discharge tubes (e.g., neon signs and sodium vapour lights)
- silicon diodes found in computers

In each case, the electric current behaves in a different way. Although there is an electron flow, the mathematical relationships are different. In the balance of this module, you are going to focus on electric current in **metallic conductors** and **electrolytic solutions**.

Metallic Conductors

Current flow in a conductor is quite straightforward, but you need to understand how it actually takes place. When an electric cell is attached to a conductor, it tends to move the electrons in the conductor. The cell acts on the electrons to push them from the negative electrode of the cell, through the conductor, to the positive electrode of the cell.

An electrode is a small piece of metal through which electricity travels.

Negative electrode  Positive electrode

Metallic atoms are joined together to form what is called a crystal lattice structure. The crystal lattice structure produces characteristic metal properties that you have already studied (or will soon study) in the chemistry cluster.

These properties include

- bending without breaking
- being able to be drawn into wire or hammered into thin sheets (ductility and malleability)
- shining
- conducting electricity

The ability to conduct electricity is characteristic of all metals but some metals are better at it than others. Copper is a good conductor.

Copper's ability to conduct electricity is a result of its tendency to have some electrons that are not attached to any atom, but are instead "wandering about." These electrons are easily moved among the crystal lattice. There are two kinds of **electron movement** in the copper when the electric cell is attached.

- **Random movement:** The electrons move from atom to atom in a random movement. Most electron movement occurs in this fashion. If more cells are added to make a battery, the electron movement becomes faster and the electrons hit the atoms with more energy.
- **Drift velocity:** As the electrons move randomly they also move slowly from the negative to the positive electrode of the battery. This slow movement of electrons is called drift velocity. While the drift velocity is very slow, the effects of the drift velocity take place at the speed of light. It is as if the conductor were filled with small steel balls. When one ball is moved at one end of the conductor, all the balls move, including the ones at the other end of the conductor. For this reason, the effect of turning on a light switch is immediate, instead of having to wait.

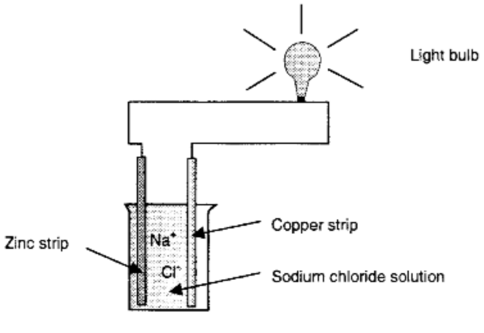
The Voltaic Cell

The voltaic cell allows the production of huge amounts of electrons on demand until the chemical reaction in the cell stops. In other words, the voltaic cell provides an electric current.

Review some points about electricity. Key concepts include the following:

- Whenever electric charge moves in a metal conductor, only negative charges move, but whenever electric charge moves in an ionic liquid or gas solution (also called an aqueous solution), both positive and negative charges move.
- According to the particle theory, an electron is a single negative charge and a proton is a single positive charge.
- An object with a negative charge has an excess of electrons compared to the number of protons; an object with a positive charge has an excess of protons compared to the number of electrons.
- A neutral atom is one that has equal numbers of protons and electrons (if an electron is added to a neutral atom, it has become a negative ion, but if an electron is removed from a neutral atom, it has become a positive ion).
- Any **electrolyte** (e.g., acid, base, or salt, dissolved in water) forms positive and negative ions.

The voltaic cell shown below illustrates the basic components in the production of electric current.

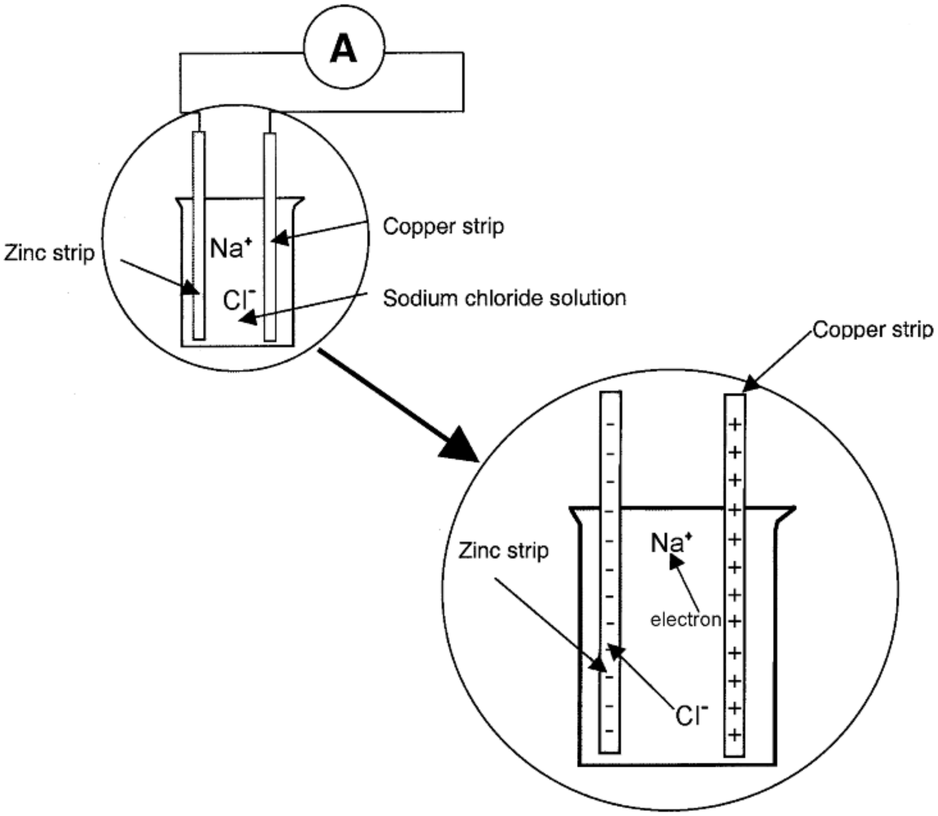


Note that sodium chloride dissolves in water to form sodium ions (Na+) and chloride ions (Cl–).

Table salt (sodium chloride) is dissolved in water. In the process, the sodium chloride separates to form positive sodium ions and negative chloride ions. The sodium ion has one more proton than electrons and the chloride ion has one more electron than protons. This aqueous sodium chloride solution is called an electrolyte.

The sodium chloride solution in the diagram below shows only one sodium ion and one chlorine ion because of limited space for the text. There are many ions in the solution.

The copper strip gives off electrons to the sodium ions and the zinc strip takes in electrons from the chloride ions. Electrons build up on the zinc and an absence of electrons (positive charge) builds up on the copper. If a conductor connects the copper and zinc, electrons travel from the zinc to the copper as shown in the following diagram.



The sodium ion absorbs an electron from the copper, leaving the sodium ion neutral and the copper with a positive charge

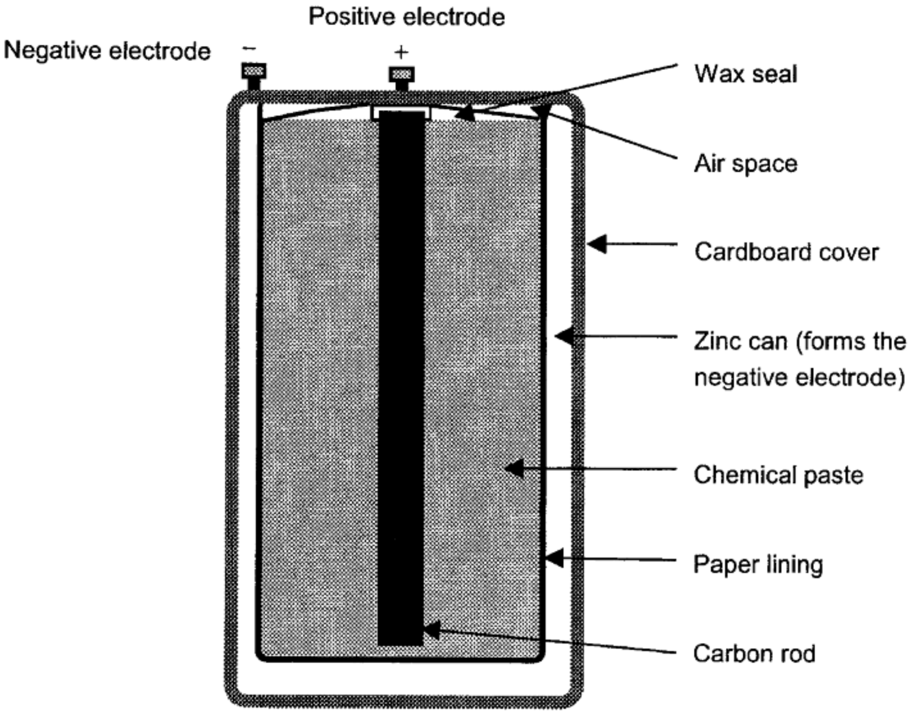
The chloride ions give off electrons to the zinc, leaving the zinc negatively charged.

The copper strip becomes positively charged and is called a positive electrode. The zinc strip becomes negatively charged and is called a negative electrode. Every cell has a positive and negative electrode. The electrodes are made of different materials, and there must always be a positive and negative electrode in a cell.

The copper wire conductor forms an external circuit or conducting loop usually made of copper wire. The electron flow is from the zinc to the copper electrode. In the circuit above, an ammeter measures the movement of electrons through the copper conductor. An **ammeter** is a tool used to measure electric current in a conducting loop.

Dry Cell

The **voltaic cell** is a wet cell because the electrodes are surrounded by a water solution containing an acid, base, or salt. The **dry cell** uses a paste which is also an acid, base, or salt solution. While the dry cell is not really dry, the paste is thick enough for easy handling and it is used in many different electrical devices.



The dry cell shown in the diagram above is a standard cell. Many of the dry cells used today have the negative electrode at the bottom of the cell. In this way, the cells are joined together by placing them one on top of the other.

Learning Activity 3.8: Dry Cells

1. Name four ways that dry cells are used.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

2. When sodium chloride is dissolved in water to form the solution for a voltaic cell, an ionic solution is formed.

   a. Write the symbol for the ions and the name of each.

   b. State which ion gains electrons and which loses electrons.

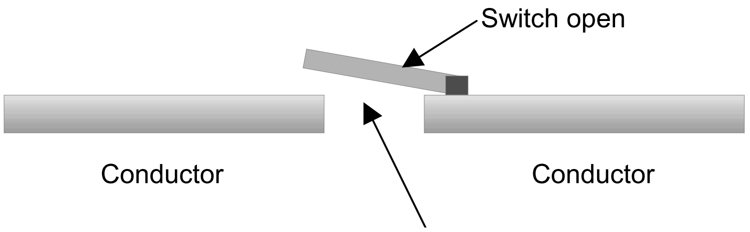
   c. What is the charge left on the copper electrode?

Check the answer key.

Open and Closed Circuits

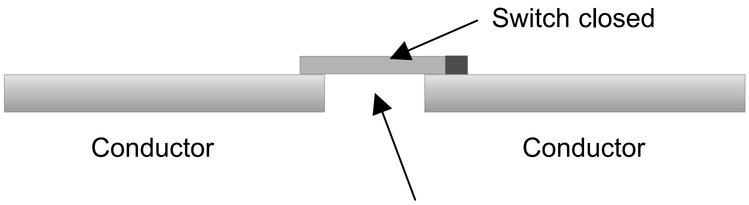
In order to have a working circuit, you must have a closed loop so that the electrons can have a continuous path to travel. In a circuit, the conducting loop can either be opened or closed.

Open Circuit



An open circuit has a break in the copper conductor that would prevent the flow of electrons through it.

Closed Circuit



A closed circuit is touching the other side of the conductor providing a path for the electrons to travel as shown in the diagram.

A closed circuit does not have a break and electrons would flow through the copper conductor. A circuit can easily be opened or closed by using a switch. Like a lightswitch, when the switch is on, the circuit is closed; when the switch is off, the circuit is open.

Try it!

1. Open the *Crocodile Clips* software.
2. Select create a circuit.
3. Select a battery, SPST switch, and light bulb, and connect them all together.
4. Click on the switch to turn it on and off. What do you notice?

Coulombs

When the circuit is closed, electrons travel through the light bulb, as in the voltaic cell diagram earlier in this lesson. An ammeter can take the place of the light bulb. The ammeter measures the number of electrons that travel through the circuit. The counting process, however, does not involve counting the electrons one by one; rather, it uses the effect of the movement of electrons to register on the ammeter. One electron moving through the circuit has no effect on an ammeter. Even 10 000 electrons moving through the circuit will not affect the ammeter.

The ammeter begins to register some measurement when there are a huge number of electrons (called a coulomb (C) of electric charge) passing through the conductor. A coulomb (pronounced coo-loam) consists of 6.25 billion billion or 6.25 x 1018 electrons. [The number 6.25 x 1018 is the number 6 250 000 000 000 000 000 expressed in scientific notation. Scientists and mathematicians use scientific notation to show really large or really small numbers in a simpler way. 6.25 x 1018 can also be expressed as 6.25 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10 x 10. The "18" in 6.25 x 1018 means that you need to multiply the 6.25 by 10 eighteen times.] This huge number of electrons must pass through the ammeter in one second for it to register a rate of flow of one coulomb per second or one ampere (A) (1 C/S = 1A).

Rate of Flow

The concept of rate of flow is especially important at this point. Rate of flow is applied to many different situations. To determine the rate of flow of traffic, you stand on the edge of the road and count the number of cars passing that point in a certain period of time. The rate of traffic flow is then expressed, for example, as 24 cars per minute. Rate of flow has many applications in science and technology.

In electrical terms, the rate of flow of charge is expressed as electric current by calculating the number of coulombs of electric charge that pass a section of the conductor in a second. The standard for measuring electric current is amperes. An ampere is one coulomb of electric charge passing a section of the conductor in one second.

If given the task of measuring a river's rate of flow and you are told to measure it in water molecules per second, it would be impossible to do. It is impossible to actually count molecules of water. The only way to measure the flow is in pails of water per second (i.e., in quantity of water over time).

$$\text{Rate of flow} = \frac{\text{Quantity}}{\text{Time}}$$

To determine the current of a small stream, you may direct it through a pipe and collect the water in a pail. You discover that it takes five seconds to fill 10 pails of water. You can determine that two pails are filled every second. This means the current of the stream is 2 pails per second.

In somewhat the same way, it is impossible to measure electric current in electrons per second, so a measurable unit is called a coulomb per second.

In review, remember that the flow of electricity through a conductor is measured as amperes.

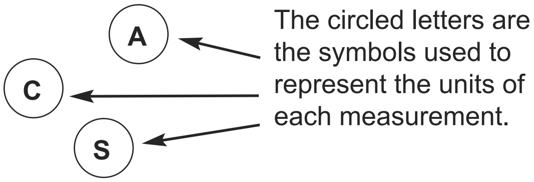
1 ampere = 1 coulomb/second passing a certain section of a conductor

One coulomb of electricity is a quantity of electrical charge like a pail of water is a quantity of water.

It is often an advantage to replace words in a formula with symbols. Symbols make the formula shorter and easier to understand.

Substitute symbols for words in the following:

- I = current (amperes)
- Q = coulombs
- t = time in seconds



The circled letters are the symbols used to represent the units of each measurement.

The formula now can be written:

$$I = \frac{Q}{t}$$

The formula shown above is used to calculate current in any conductor as long as the number of coulombs travelling past a section of the conductor, and the time it took the coulombs of electric charge to travel, are known.

Example

A voltaic cell is producing 2.6 coulombs of electricity every 2.0 seconds. What is the current flowing through the ammeter?

$$I = \frac{Q}{t}$$

Q = 2.6 Coulombs

t = 2.0 seconds

I = 2.6 C/2.0 s

= 1.3 C/s (Coulombs per second) or

= 1.3 Amperes

Notice that coulombs/second and amperes are different names representing the same unit.

The method used in solving the problem above is a good model. Use it whenever you solve word problems by

- identifying the basic formula and writing it down

  $$I = \frac{Q}{t}$$

- writing down the values for the other parts of the equation

  Q = 2.6 C
  t = 2.0 s

- placing the values and the units into the formula

  $$I = \frac{2.6\ C}{2.0\ s}$$

  $$I = \frac{2.6}{2.0}\ \frac{C}{s}$$

- doing the arithmetic (make certain that you include the units in the calculation, because in this way the proper units are always in the final answer)

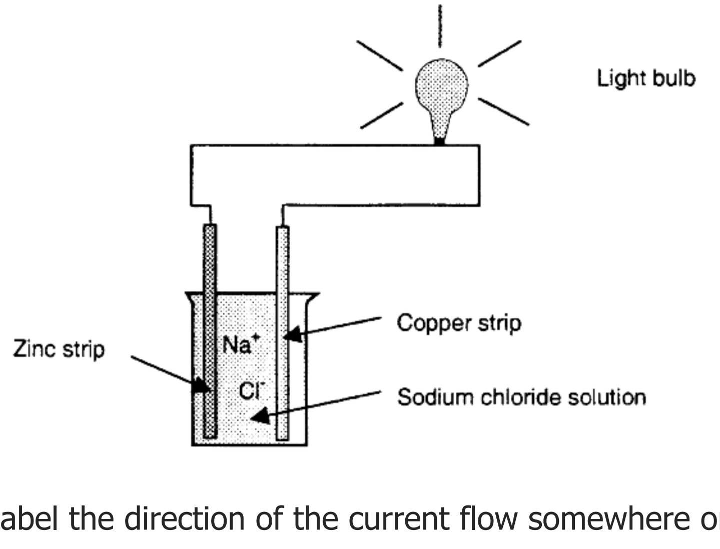
I = 1.3 C/s You can also substitute A (amperes) for C/s.

I = 1.3 A

Learning Activity 3.9: Electric Current

1. Electric current is used every day.
   a. What two measurements must be known to calculate electric current?
   b. What are two ways of expressing electric current that you have seen in this lesson?
   c. If there were 24 coulombs passing a section of conductor in 1.6 seconds, what is the electric current in the conductor?
   d. A hydraulic system pumps 25 litres of oil past a section in the hydraulic line in one hour. What is the rate of flow of the hydraulic oil?
   e. You have difficulty sleeping and decide to count sheep. The sheep jump a fence in single file. What is the rate of flow of sheep over the fence if you count 150 in five minutes?
   f. You have made a voltaic cell and connected it to a light bulb. The bulb lights up so you know there is an electric current. What needs to be done to determine a number value for the electric current?

2. Use the diagram to answer the following questions.



   a. Label the direction of the current flow somewhere on the diagram.
   b. What chemical is dissolved in the water?
   c. What happens to the chemical when it is dissolved in the water?

continued

Learning Activity 3.9 (continued)

d. What name is given to the
   Na+ ion?
   And the Cl– ion?

e. What happens between the Na+ ion and the copper strip?

f. What happens between the Cl– ion and the zinc strip?

g. Which of the two metal strips begins accumulating an excess of electrons?

h. What direction do you predict the electrons will travel on the basis of a buildup of electrons?

i. Does your answer in part (a) agree with your answer in part (h)?

j. If you wanted to measure the electric current in the circuit, how do you modify the set-up shown in this question?

k. What name is given to the type of cell shown in this question?

3. The formula for determining current in a circuit is I = Q/T. In the table below, fill in the blank spaces with the appropriate names.

Name	**Unit**	**Abbreviations**
Current		
Quantity		
Time		

4. The formula I = Q/T determines the different values for current and even values for quantity and time. Fill in the blank spaces in the table below.

I		2A	12A	
Q	5C	6C		42C
T	2s		2s	7s

Check the answer key.

Summary

- Electric current is found in many different devices, but in Grade 9 Science we consider an electric current through metallic conductors and electrolytic solutions only.
- Metallic conductors allow only electrons to travel through the conductor. Both positive and negative charges move through an electrolyte solution.
- Electric current is described as a rate of electron flow in a circuit.
- A voltaic cell uses two different metals in an electrolytic solution. A chemical reaction between the solution and the metallic electrodes creates the electric current. Chemical energy is converted into electric energy.
- A dry cell uses the same principal as the wet cell, but the electrodes are surrounded by a paste instead of a water solution.
- There is no current in an open circuit because there is a break in the conductor, preventing a flow of electrons.
- One coulomb equals 6 250 000 000 000 000 000 (6.25 billion billion) or 6.25×10^{18} electrons.
- Rate of flow is a common method used to measure the quantity of material that passes a section of a conductor in a period of time (e.g., cars per hour or litres per minute).
- In electricity, the rate of flow of electric charge is measured in coulombs of charge per second or amperes. One ampere equals one coulomb of charge passing a section of conductor in one second.

LESSON 8: ELECTRIC POTENTIAL

Lesson Focus

After completing this lesson, you will be able to

☐ define electric potential
☐ use the concept of electric potential to solve problems
☐ relate electric potential to electric circuits

Key Words

- electric potential
- electromotive force
- joule
- voltage
- volt

What Is Electric Potential?

Whenever electric charges move through a conductor, work must be done on them. If work is done on the electric charge, there must be some energy applied. The energy applied to any circuit causing movement of electric charge is called **electric potential (potential energy)**.

Potential energy is a common and welcome source of energy in many situations. We can describe potential energy as stored energy. Once the stored or potential energy is released it is capable of doing work.

Potential energy can exist in many forms. A stone on the edge of a cliff is an example of gravitational potential energy. If the stone is released and falls downward, it will do work, in a destructive way, on anything it hits. Gasoline is an example of thermal potential energy. Gasoline burned in an engine can do large amounts of work.

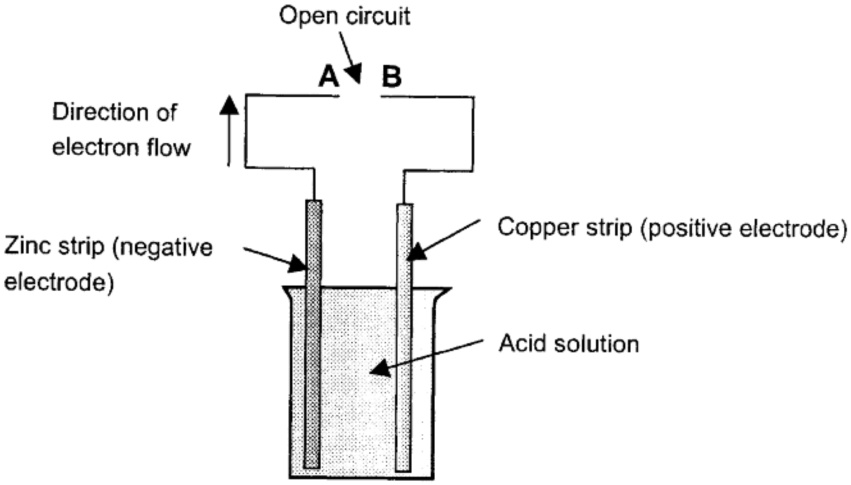
One of the easiest ways for us to understand the meaning of potential energy is to look at an example. A bricklayer is building a wall. He bends over and picks up a brick and places it on the top of the wall. The brick now has some gravitational potential energy. The brick is accidentally knocked off the wall and falls down, landing on the bricklayer's toe. The potential energy of the brick has been changed into work done on the toe, much to the bricklayer's discomfort.

The change from potential energy to work is a common occurrence in our world. Our understanding of this relationship and our ability to harness it in beneficial ways is one of the outcomes of science and technology.

The brick in our example demonstrates two characteristics of potential energy:

- The brick could have stayed on the wall for a long time. In this way, it represents stored energy.
- The brick could also have been moved off the wall at any time, whenever the work needed to be done. The ability to provide work on demand is another characteristic of potential energy.

Electric Potential—Voltaic Cell



In the open circuit above, the zinc strip causes electrons to build up at point A and a deficiency of electrons at point B, creating an electric potential. If a switch is inserted in the circuit above, we can cause the electric potential to do work by simply closing the switch and allowing an electron flow (a current) to take place as the electrons flow from the negative to the positive electrode.

An open circuit voltaic cell qualifies as a source of potential energy because

- the potential energy is stored for as long as the switch is open
- the potential energy is an "on demand" energy source since you can choose to allow the potential energy to do work by closing the switch whenever you want

The potential energy created by an open circuit is called the emf (electromotive force) of the circuit. The term electromotive force is an outdated term because energy is not just force. Emf is retained, even though the concept is incorrect, because of its historical context.

We have been talking about changing potential energy into work. Some examples illustrating electric potential energy changed into work are listed below.

- An electric saw converts electric energy into work done cutting a board.
- An electric starter converts electric energy into work done cranking a car engine to start it.
- An elevator converts electric energy into work done moving people from one level to another in a building.

This is a good time to look at a model of an electric circuit. A circuit consists of an energy source that has some potential energy, a pathway for charges to travel, and a device, such as a light, an oven, et cetera, that requires energy to operate (there can also be a measuring device such as an ammeter).

To illustrate how an electric circuit works, imagine four strong people at one end of a tube that is filled with marbles. The four people are standing around, waiting to go to work. They represent electric potential. On a signal, they begin pushing on the marbles with a plunger. As soon as the marbles move one centimetre on their end of the tube, the marbles move one centimetre at the other end of the tube. The energy that they have put into the marbles has travelled instantly through the whole system.

If we want, we can put a marble counter anywhere in the tube and it will count the number of marbles per second passing by. It won't be able to count individual marbles but it might be able to count groups of 1000 marbles to give us a measure of the rate of flow in groups of 1000 marbles per second.

Also, if we want, we can attach a machine to the tube that uses marbles to make it run. At least some of the energy that the young people use to push marbles through the tube is being used up to run the machine attached to the tube. If the four strong people are pushing 100 packets of marbles through the tube and these packets are capable of doing 400 **joules** of work, we could say the potential these strong people have for doing work is 400 joules/100 packets or four joules per packet of marbles.

Voltage

Once a circuit is closed, we use the word **voltage** to tell us how much energy is needed to do the work of moving electrons through the circuit. If it takes one joule of energy to move one coulomb of electric charge through some distance on a conductor, we can say that **one joule per coulomb** or **one volt** of electric energy was needed. Let's look more closely at the description above:

- The **joule** is a standard unit of energy in the metric system. Work is also measured in joules. Energy needed to do the work, in this case the work in moving electrons, is measured in joules.

  James Joule was a British scientist who had his own laboratory. Joule made many discoveries in physics that related to work and energy. It is in his honour that the unit of energy in the metric system is called a joule.
- One coulomb of electric charge is 6,250,000,000,000,000,000 (6.25×10^{18}) positive or negative charges.
- The **volt** is a common term used to represent one joule of energy used to move every coulomb of electric charge. The volt is named for Alessandra Volta.

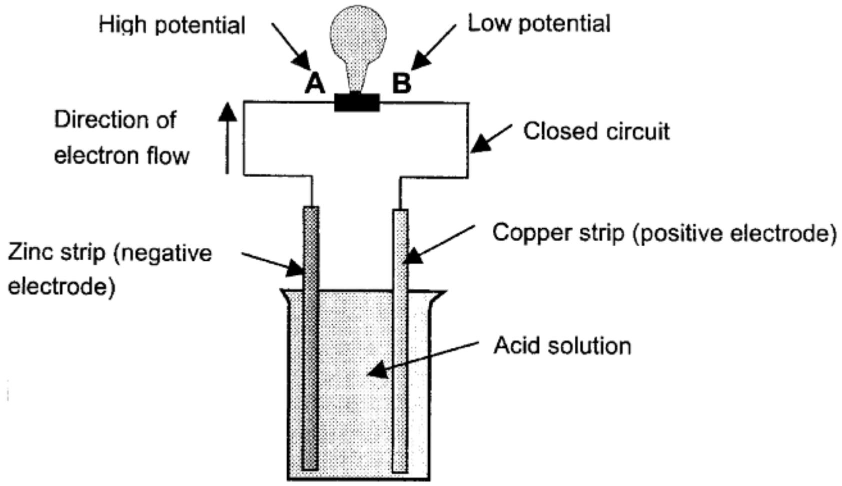
$$\boxed{V = \frac{E}{Q}}$$

$$\text{Potential delivered} = \frac{\text{total energy (work done)}}{\text{number of coulombs of electric charge}}$$

  - V is the potential in volts (joules per coulomb).
  - E is the work in joules.
  - Q is the charge in coulombs.

- Whenever work is done, potential energy is lost. For example, the brick that fell on the worker's foot had a larger gravitational potential energy when it was on the top of the wall. As it fell, its potential energy decreased but its ability to do work increased until it hit the worker's foot. The amount of potential energy lost in the fall would equal the amount of work done on the worker's foot.
- In electric circuits, the potential energy is greatest at the negative strip (electrode) of the cell. Electrons do work as they move from the negative electrode. As a result, the electric potential decreases until it is at its lowest value at the positive electrode.

The voltaic cell in the diagram below shows an electric bulb connected to the circuit.



As the electron current travels through the circuit, electrons will travel from point A to point B. The electrons at point A have a higher potential energy than the electrons at point B. The electrons travelling from point A to point B do work in turning the filament of the light bulb white, causing it to give off heat and light. The amount of electrical potential lost between A and B is equal to the amount of work done on the light bulb.

Sample Question

If an electric cell is able to provide one coulomb of electric charge with three joules of potential energy to a device in the circuit, we can calculate the voltage of the battery.

$$V = \frac{E}{Q}$$

$$= \frac{3J}{1C}$$

$$= 3\ J/C$$

Since 1 J/C = 1 volt, we can say that we are working with a three-volt battery.

Learning Activity 3.10: Potential Energy

1. An electric cell is able to provide 4 coulombs of electric charge with 8 joules of potential energy to a device in the circuit. What is the voltage of the battery?
2. A battery has a potential energy of 1.5 volts. If the battery produces 3 coulombs of electric charge, what is the total work done by the battery?

Check the answer key.

Summary

- Electric potential is the potential energy needed to move electric charge through a circuit.
- Electric potential in electrostatics can be established by separating charges by friction (e.g., charging a rod).
- Voltaic cells create electric potential through chemical reaction between the electrolytic solution and the electrodes.
- Electric potential is measured in volts.

$$\boxed{V = \frac{E}{Q}}$$

  - V is potential measured in volts.
  - E is work measured in joules.
  - Q is the quantity of electric charge in coulombs.

When an electric appliance or resistor is used, electrons enter with a high potential, do work on the appliance or resistor, and leave with a lower potential. The electric energy used by the appliance or resistor is changed to heat energy, light energy, or some other form of energy.

Based on electron flow, high potential is located at the negative electrode and low potential at the positive electrode.

Notes

LESSON 9: PRODUCING ELECTRICITY

Lesson Focus

After completing this lesson, you will be able to

☐ state five different sources of electric potential
☐ state the energy transfer that takes place in each source

Key Words

- kinetic energy
- chemical potential energy
- thermoelectric effect
- thermocouple
- thermopile
- photoelectric
- piezoelectric
- electromagnetic

Producing Electricity

In Lesson 8, you learned that electric potential was responsible for moving electric charge from one place to another. This lesson explores some ways that electric potential is produced.

To create electric potential energy, we must build up and separate charge. As the negative charges move, the energy is transformed into **kinetic energy**. If we do not replace the negative charge, the potential reduces very quickly and no more current will flow. For a continuous flow of charge, we must maintain this building up (or accumulating of) charge. Whenever there is an electric current in a conductor, work can be done in some way.

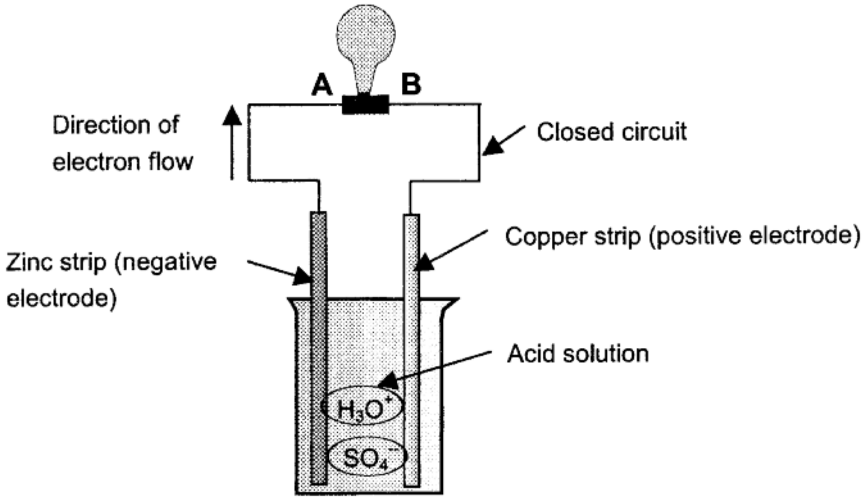
Some examples of work being done are given below:

- running an electric motor
- heating an electric stove element
- providing light from a light bulb

For work to be done, there must always be a source of energy. The energy source must be able to create a charge separation and accumulation. Five sources of potential energy that can be used to move electric charge through a circuit are described in the following pages.

Chemical Energy

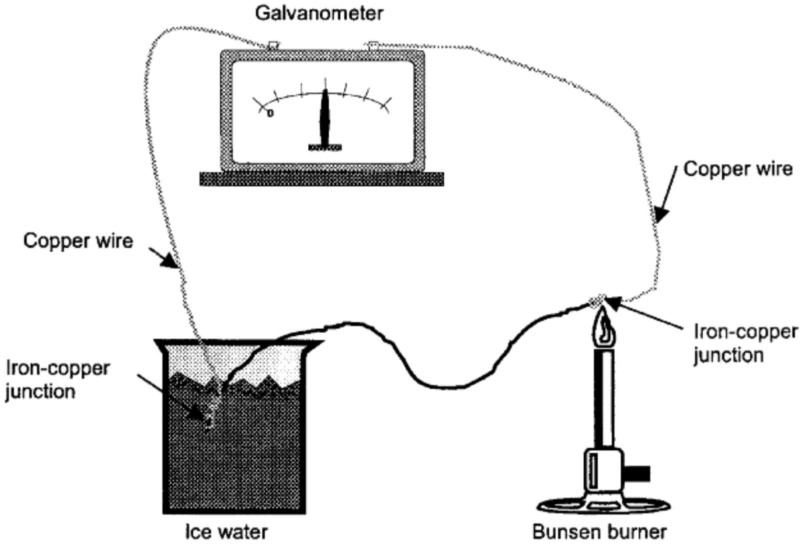
You have seen that a copper wire and an iron nail stuck in a lemon can produce an electric potential. Another example of **chemical potential energy** is the voltaic cell. Both the voltaic cell and the lemon cell work on the same principle. The chemical action deposits a charge on the electrodes of the cell.



A charge separation on the positive and negative **electrodes** provides the potential energy necessary to push electrons through the bulb, causing it to produce light.

Thermoelectric

Heat energy can be converted to electrical energy through a process called the **thermoelectric effect**. The diagram below illustrates the thermoelectric effect.



The thermoelectric effect occurs when two different metals (copper and iron in this case) are heated at one junction and cooled at another.

When one set of copper and iron junctions is used, the set-up is called a **thermocouple**. When several combinations are used in series, the result is called a **thermopile**.

Thermocouples are used as temperature measuring devices (e.g., the temperature gauge in a car). As the engine heats up, more current travels through the circuit. A galvanometer placed in the dash of the car is calibrated to measure the temperature of the engine.

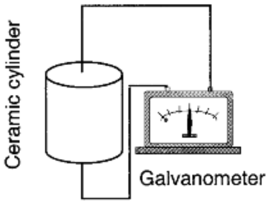
Thermocouples are also useful when conditions do not allow direct measurement. Jet engine temperature is measured using a thermocouple and the information is transmitted to the cockpit where the information can be safely read. Gas furnaces also use a thermocouple switch where a loss of heat, occurring when a pilot light goes out, causes the electric current to stop and a switch then turns the gas off at the furnace, stopping a gas leak at the furnace and a possible explosion.

Photoelectric

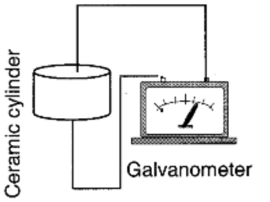
When light strikes certain materials, it has enough energy to knock electrons free. These electrons are able to create a weak electric current. This process is called the photoelectric effect. The photoelectric effect is used in camera light meters to set the exposure for the camera automatically. Automatic doors also use the photoelectric effect to open and close doors.

Piezoelectric

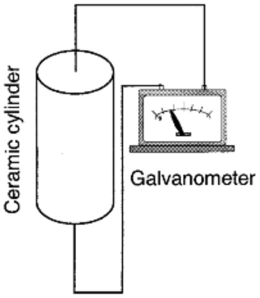
Certain types of crystals will produce an electric potential when they are pressed together. Rochelle salts, ceramics, and quartz demonstrate this property called the **piezoelectric** (pie-ee-zoe-electric) effect (piezo comes from the Greek word that means pressure).



Ceramic cylinder at rest, no electric current produced



Ceramic cylinder compressed, electric current produced as shown on the galvanometer

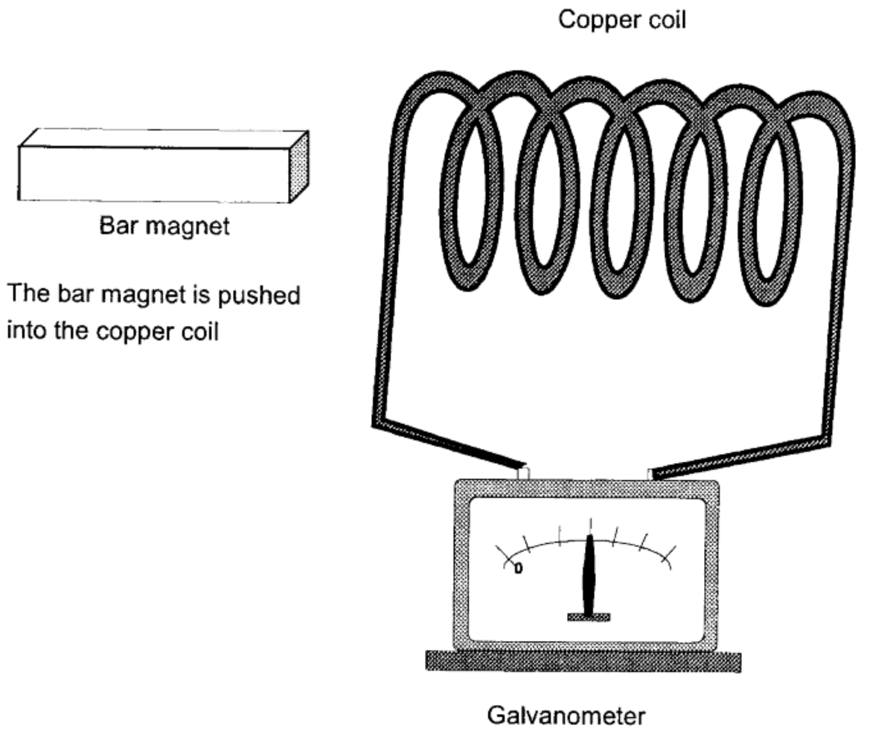


Ceramic cylinder stretched, electric current produced in opposite direction as shown on the galvanometer

The piezo effect also works in reverse. Applying an electric potential to the crystal will cause it to change shape slightly. Ultrasonic waves used in medicine are formed when an alternating current is passed through a piezoelectric crystal. The current causes rapid deformations of the crystal that in turn cause compressions in the air surrounding the crystal, or ultrasonic waves.

Electromagnetic

In 1831, Michael Faraday demonstrated that a moving magnetic field could produce a current in a coil of wire. The diagram shown below illustrates how a bar magnet can be pushed into a copper coil to produce an electric current.



When the bar magnet is pushed into the coil, the galvanometer needle is deflected. When the bar magnet is pulled out, the needle is deflected in the opposite direction.

Faraday reasoned that it would be easy to create a continuous moving magnetic field by rotating a wheel with spokes, which were conductors, between the poles of a horseshoe magnet. The result was a continuous supply of reasonably constant current. As more conductor spokes are added, the current becomes constant and a cheap, readily available supply of electricity has been achieved. This supplier of electricity became known as an electric generator.

A source of energy needed to turn the generator was at first supplied by steam engines but the most common source of potential energy today is the hydroelectric dam.

Learning Activity 3.11: Types of Electricity

1. Who discovered the connection between electricity and the moving of a conductor through a magnetic field?
2. What happens to the current when a bar magnet is pushed into and pulled out of a coil of copper wire?
3. Name at least one device that uses the piezoelectric effect to produce a weak electric current.
4. Why is a thermocouple an important part of your car?
5. Which of the five different methods of producing electricity described in this lesson is used to provide electric energy for your home?
6. How did Faraday design an apparatus to get a constant current?

Check the answer key.

Summary

Electric potential energy is produced from other energy sources:

- chemical energy
- thermoelectric energy
- photoelectric energy
- piezoelectric energy
- mechanical energy in generators (electromagnetic)

Assignment 3.3: Producing Electricity (27 marks)

1. Explain two characteristics of potential energy by using a dry cell as your example. *(2 marks)*

2. If 16 coulombs of electricity pass a section of conductor in 4 seconds, what is the current in the circuit? *(2 marks)*

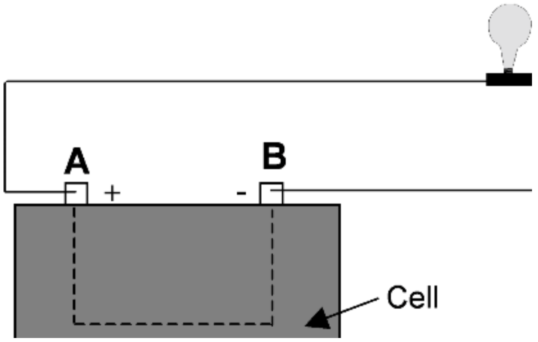
3. A battery is able to supply 6 joules of energy to 2 coulombs of electric charge in a circuit. What is the potential of the battery in J/C? *(2 marks)*

4. When an electric current passes through appliances and tools, an energy conversion takes place. What is electric energy changed to (e.g., thermal energy, gravitational energy, heat energy, chemical energy, mechanical energy) in the following cases? *(2 marks)*

   Electric saw ______________________________

   Electric barbecue ______________________________

5. Use the diagram to answer the questions below. The battery is able to provide 48 joules to 4 coulombs of charge. Four coulombs take one-half second to pass a section on the conductor.



a. Draw the direction for conventional current on the diagram using a labelled arrow. *(1 mark)*

b. According to electron current, would electrode A or B have the highest potential? *(1 mark)*

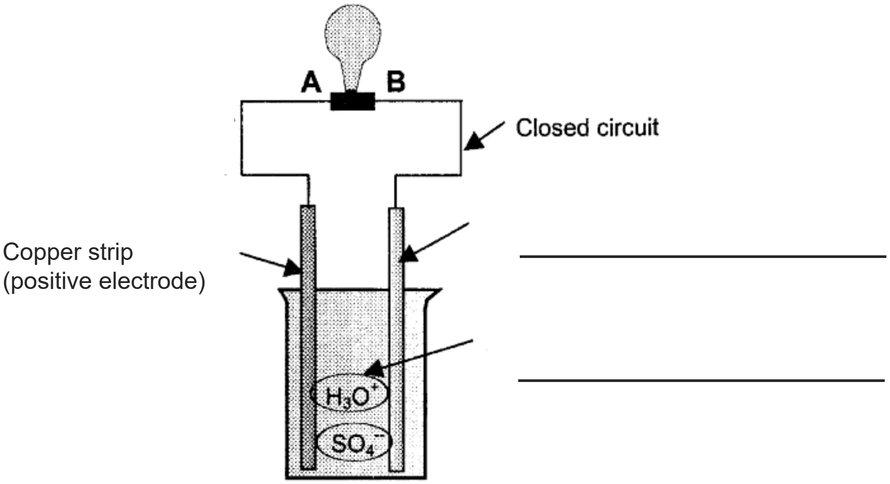
c. What is the electric potential developed by the battery? *(2 marks)*

d. What is the electric current produced by the battery? *(2 marks)*

e. How does the battery keep producing high potential electricity? *(1 mark)*

6. Describe the difference between an electron and a coulomb of charge. In your description, use a molecule and a pail of water for comparison. *(2 marks)*

7. The diagram below shows a voltaic cell producing a current that is able to light a bulb. The diagram has been changed slightly from the one shown earlier. Use the diagram to answer the following questions.



a. Place the remaining two labels on the diagram. *(2 marks)*

b. Use an arrow to show the direction of flow of the electrons in the circuit. *(1 mark)*

c. What kind of energy conversion is taking place? *(2 marks)*

   i. Inside the cell ____________________________

   ii. At the light bulb ____________________________

d. The zinc strip or electrode is part of the process of producing an electric current. *(3 marks)*

   i. What is the charge on the zinc electrode?

   ____

   ii. Do electrons travel toward or away from the zinc electrode?

   ____

   iii. What happens to the electrons of the sulphate ion at the zinc electrode?

   ____

e. In a few sentences, describe how the voltaic cell produces an electric current. *(2 marks)*

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LESSON 10: SIMPLE CIRCUITS

Lesson Focus

After completing this lesson, you will be able to

- ☐ draw simple schematic diagrams
- ☐ predict what happens to voltage and current when cells are connected in series or parallel
- ☐ demonstrate an ability to connect a conductor, a dry cell, and a light bulb so the bulb will light up
- ☐ demonstrate that the direction of an electric current has no bearing on its producing light in a bulb
- ☐ define and demonstrate a short circuit

Key Words

- conducting loop
- resistance
- load
- series circuit
- battery
- schematic symbols
- parallel circuit
- short circuit

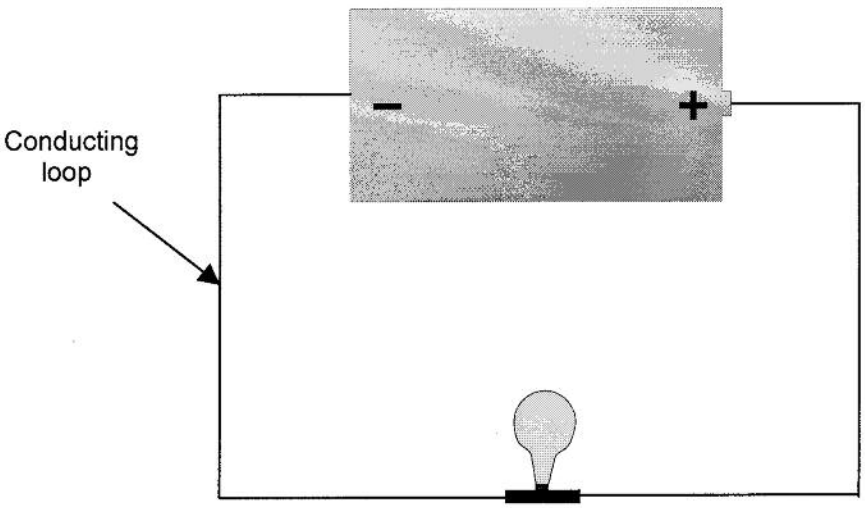
Basic Circuits

In their most basic form, circuits consist of (1) a source of energy, (2) a **conducting loop**, and (3) a **resistance (from a load)** that uses electrical energy.

Lesson 9 explored five different sources of electrical potential energy. Each of these sources is capable of producing the electrical potential energy needed to produce an electric circuit.

A conducting loop consists of a copper wire attached to the battery and the load in such a way that a path exists for the electrons to travel. The load in a circuit can be a light bulb, an electric motor, or any other electric device.

A dry cell is the source of potential energy.



Load (light bulb)

A load uses the electric potential energy contained in the battery to produce other forms of energy. A motor uses electric potential to produce mechanical energy, while an electric stove uses electric energy to produce heat energy.

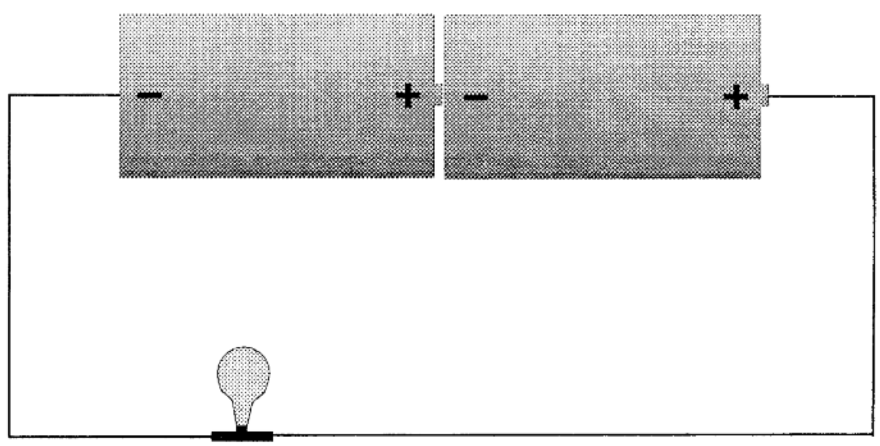
When an electric current travels through a circuit, there is some opposition to the flow of electrons because of resistance. The electrons travelling through the material making up the resistance are bumping into its atoms and transferring some energy to them. An illustration of this situation is someone trying to run through a crowd of people, moving back and forth through the crowd, seeking openings. Eventually, this person reaches his or her destination, but is delayed considerably by the crowd. This person would also bump into people, transferring energy to them.

The type of material in the load determines the resistance to the flow of electricity. The resistance may be small. In this case, the electrons pass through easily and the current is hardly affected. Sometimes the resistance to the movement of electrons is strong. In these cases, the electrons hit more metal atoms and the current is reduced.

Nichrome wire has a strong resistance to the flow of electrons. As a result of the electrons bumping into the fixed particles of the nichrome atoms, energy is transferred to the nichrome wire in the form of heat. In a light bulb filament, the heat energy is great enough to cause the filament to glow a bright white and give off enough light for us to use it in a light bulb. Copper, gold, silver, and aluminum offer little resistance to the flow of electrons; for this reason, copper is commonly used for electrical wiring.

Cells in Series

Two dry cells in series



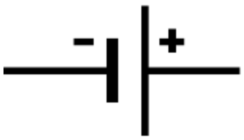
Load (light bulb)

Two dry cells are connected in **series** to form a **battery**. The term battery means several cells. When cells are connected in series to form a battery, they are placed with the positive end of one cell in contact with the negative end of the next cell as shown in the diagram above.

The reason for placing cells in series is to increase the voltage of the battery. If the two cells have a voltage of 1.5 volts each, the result of the series connection is a battery with a voltage of 3.0 volts. In this way, the voltage of a battery is increased to the point where there is enough potential energy to cause the electrons to flow. The light bulb in this example, therefore, requires a voltage of 3.0 volts. When cells are placed in series, however, the amount of current they can produce remains the same as a single cell.

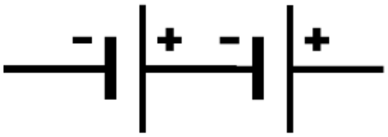
Schematic Symbols

Sometimes drawing pictures of the objects involved in a circuit takes too much time, so a system of symbols called schematic diagrams are used to make the task easier. A cell schematic is shown below.



The short stroke represents the negative electrode and the long stroke represents the positive electrode.

The placing of cells in series can be shown using the schematic below.



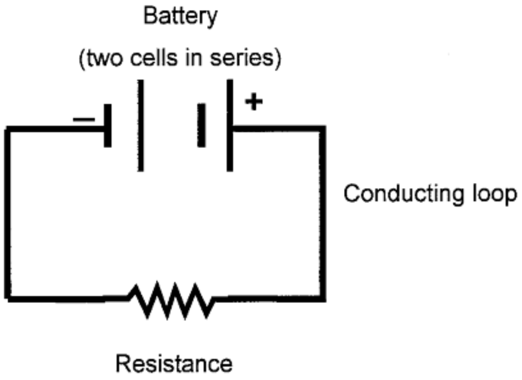
The positive and negative electrodes are shown as being connected.

Resistor

Light bulb

A resistance is shown as a wavy line (at left).
A bulb is shown as a circle with a coil inside.

A basic circuit shown in schematic form is drawn below.



Use the *Crocodile Clips* software available at www.yenka.com/en/Free_student_home_licences/ to make a circuit that would match this schematic diagram.

Other schematic symbols are useful.

Open switch (no current)

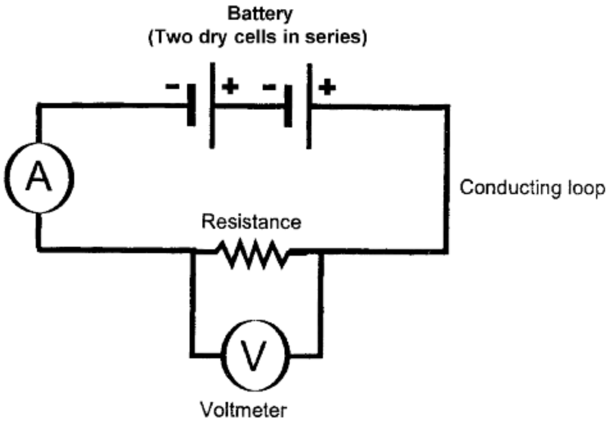
Closed switch (current)

Ammeter

An ammeter is used to measure the current in a circuit. An ammeter must always be connected in the circuit (in series).

Voltmeter

A voltmeter is used to determine the electric potential energy available across any set of resistors. A voltmeter is always connected across a resistance or set of resistances.

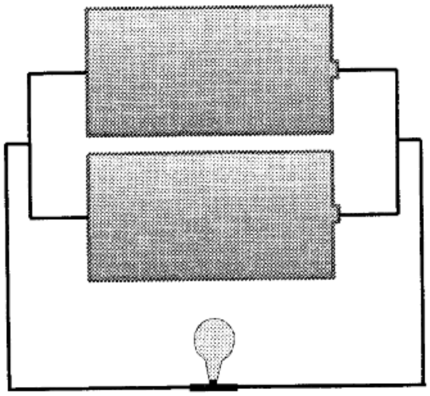


The ammeter is placed in the circuit and the voltmeter is placed across the load. An ammeter is placed in the circuit so that all the charges flowing through the conductor will pass through it. Placing the ammeter in the circuit allows it to measure all the current in the circuit.

The voltmeter is measuring the electric potential across the resistance. Notice that one end of the voltmeter is placed on one side of the resistance and one end on the other side. In this way, the voltmeter is able to measure the difference in electric potential energy between the two sides of the resistance. We can say the voltmeter is measuring the potential difference across the resistance. This is a measure of the electric energy needed to operate the load.

Cells in Parallel

It is possible to place cells together to form a **parallel circuit** by joining the positive electrodes together and the negative electrodes together. Cells in parallel form a battery that has the same voltage as a single cell. Each cell contributes a portion of the total current available to the circuit. Cells in parallel can deliver the same current as a single cell for a longer period of time or provide more current than a single cell. Remember the resistance of the circuit determines the amount of current in a circuit.



Two cells are connected in parallel. The two positive electrodes are connected and the two negative electrodes are also connected.

The chart below is a summary of the effects of joining cells in parallel and series.

	Cells in Series	**Cells in Parallel**
Current	Total current for all cells is equal to the current from a single cell.	Total current is equal to the sum of currents from each cell.
Voltage	Total voltage is equal to the sum of voltages from each cell.	Total voltage is equal to the voltage from a single cell.

Learning Activity 3.12: Simple Circuits

A learning partner may help you in Option 2 of this learning activity.

There are two options for this learning activity:

Option 1:

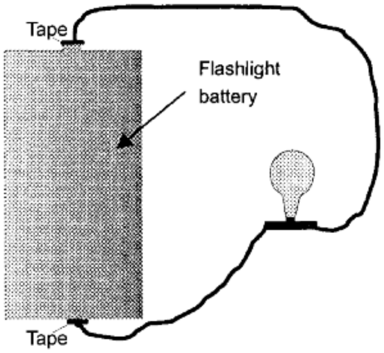
This option requires access to the Internet to use the *Crocodile Clips* software found at www.yenka.com/en/Free_student_home_licences/. You can simulate the circuits described below using this software.

Option 2:

You will need the following materials:

- 2 D cell batteries
- 1 small flashlight bulb
- light gauge wire
- transparent tape to attach the wire to the batteries and bulbs

1. Use some light gauge wire and connect one cell and one bulb together as shown. Record your observations.



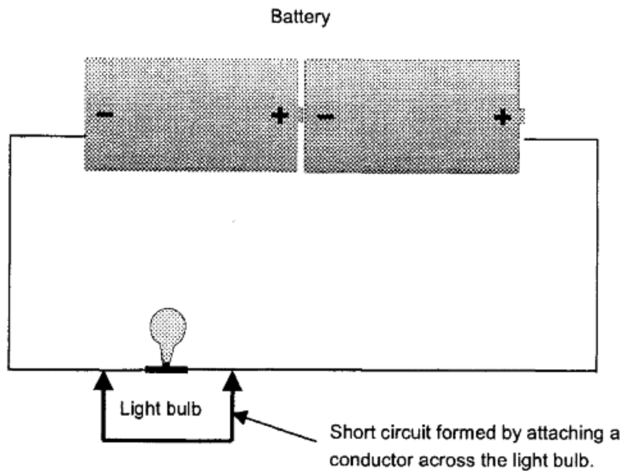
2. Connect the cells in series, as shown in the "Cells in Series" diagram earlier in this lesson, and attach them to the bulb. Compare the brightness of the bulb to the one in question 1. Explain.
3. Connect the cells in parallel, as shown in the "Cells in Parallel" diagram earlier in this lesson, and attach them to the bulb. Compare the brightness of the bulb to the one in question 1. Explain.

continued

Learning Activity 3.12 (continued)

4. Explain the difference in current between the circuit in question 1 and the one in question 3.
5. Modify the cells and the bulb in question 1 to reverse the connections and change the direction of the current. What effect does this have on the light produced by the bulb?

   Use a piece of wire with clips on both ends to create a **short circuit** on the circuit.



Caution:

The wire should only be attached briefly, as the conductor can heat up quickly. Flashlight batteries have low voltages and are safe to use but it is not safe to short a circuit with greater voltages. A **short circuit** occurs when a current has a choice between travelling through a load such as a light bulb or through the short-circuiting conductor. Electric current always travels through the path of least resistance, so in this case the current will travel through the conductor. The conductor heats up if it is a thin wire because of the large current travelling through.

Check the answer key.

Summary

- A basic circuit consists of a source of electric energy, a conducting loop, and a load. The load can be any appliance or resistor.
- Electric resistance is the resistance to the flow of electrons that is found in any material that is not cooled to superconductor status. Conductors such as copper, aluminum, and silver offer less resistance to the flow of electric current than insulators such as rubber and ceramics.
- Cells can be connected in series and in parallel.
- For cells in series, the voltage of each cell combines to give a total voltage.
- For cells in parallel, the voltage is the same as one cell and each cell contributes a portion of the current.
- Schematics are electric diagrams that make use of symbols to represent various electrical components of a circuit, for example,  represents a resistor.

Notes

LESSON 11: SERIES AND PARALLEL CIRCUITS

Lesson Focus

After completing this lesson, you will be able to

- ☐ connect bulbs in series and parallel
- ☐ explain the different brightness of bulbs in series and in parallel circuits
- ☐ set up various combinations of bulbs and explain your observations

Key Words

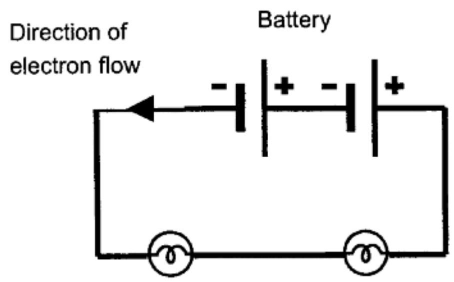
- series circuit
- Ohm's law
- ampere

Series and Parallel Circuits

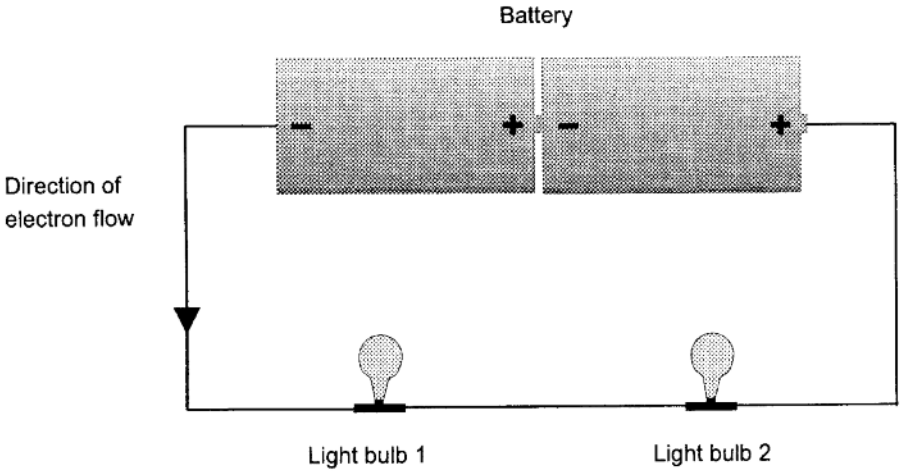
Series Circuits

Series circuits are connected in such a way that all the current must pass through each of the resistors in the circuit. If the circuit is open at any point, no current passes through any of the resistors.

Schematic



Representational



Learning Activity 3.13: Circuits

A learning partner may help you in Option 2 of this learning activity.

There are two options for this learning activity:

Option 1:

This option requires access to the Internet to use the *Crocodile Clips* software found at www.yenka.com/en/Free_student_home_licences/. You can simulate the circuits shown in the diagram above using this software.

Option 2:

You will need the following materials:

- 2 D cell batteries
- insulated copper wire
- transparent tape to attach the wire to the batteries and bulbs
- 2 small direct current bulbs (flashlight bulbs)

Connect the cells and light bulbs as shown in the diagram above. Connect two D cell batteries in series placing the positive electrode of one in contact with the negative electrode of the other. Tape the two batteries together in order to keep them in contact.

continued

Learning Activity 3.13 (continued)

Visually check the brightness of the two bulbs. The brightness of the bulbs is a method for determining the current available to the resistance. A brighter bulb is receiving more current.

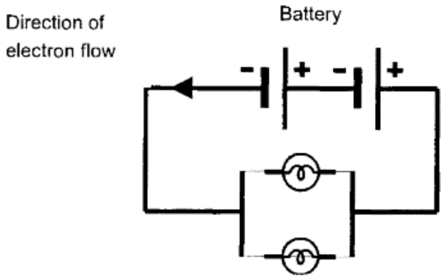
1. Are the bulbs the same brightness?

Check the answer key.

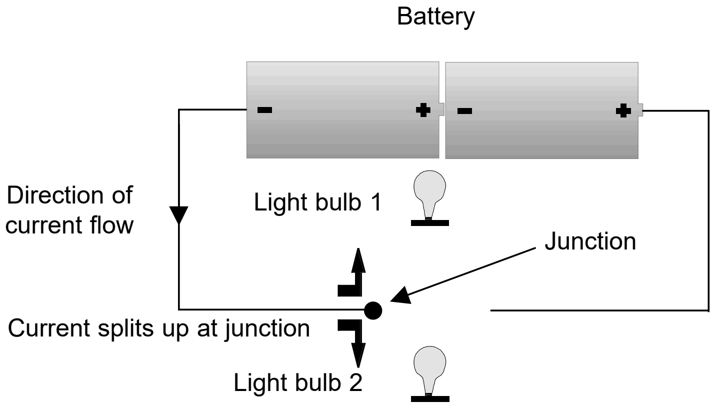
Parallel Circuits

Parallel circuits arrange resistors in such a way that a junction will allow the current a choice of branches to travel through. The resistance of the branch determines the amount of current traveling through any branch. A higher resistance means less current travels through the branch. In the diagrams below, there is a junction where the two light bulbs are located. The current splits at the junction and some flows through light bulb 1 and some flows through light bulb 2.

Schematic



Representational



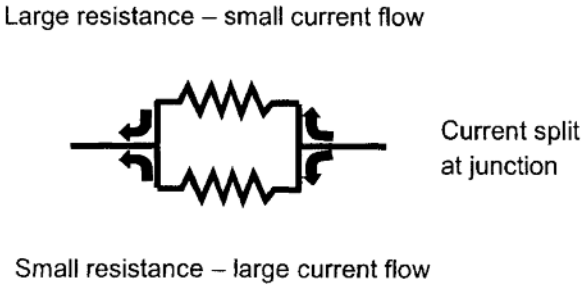
Learning Activity 3.13 (continued)

2. Modify your series circuit into a parallel circuit as shown in the diagram above. Visually check the brightness of the two bulbs. How does their light compare with the bulbs in the series circuit?

Check the answer key.

Junctions in Parallel Circuits

A junction in a circuit is like a junction in a highway. Cars meeting a junction have a choice, either to travel in one direction or the other. Circuit junctions provide electrons the same choice; the only difference is that electrons have no particular destination in mind. Electron flow direction is based on the resistance ahead. If the resistance is smaller in one direction than another, electron flow is greatest in the direction of least resistance.

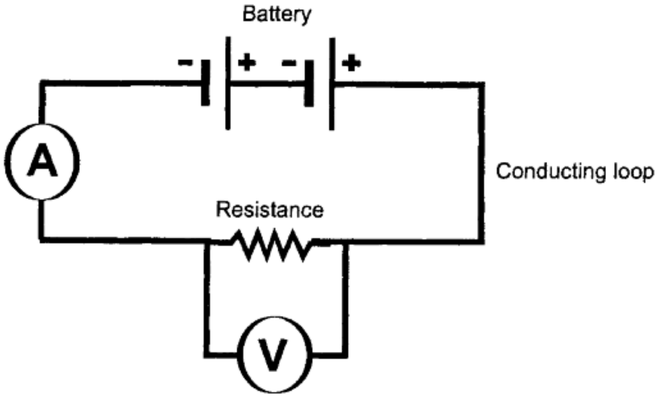


The current that split up on the right junction recombines on the left junction so that all the current in the circuit is once again moving through the same conductor. The current before the junction and after the junction has the same value. This means there has been no loss of charge as the current travels through the resistors.

Ohm's Law

The diagram below shows a basic circuit. The voltmeter is placed in parallel with the load to measure the electric potential across the load. The ammeter is in series with the load and measures the current traveling through the load.

If you add or remove cells from the battery, the current and voltage available to the circuit will rise or fall accordingly.



If you measured the ratio of voltage over current each time the battery was changed, you would notice that the ratio never changes. The constant was first detected by Georg Ohm. The result of the ratio is called the resistance of the resistor and is measured in **ohms (Ω).**

An ohm is that resistance which requires a potential of 1 volt to produce a current of one amp in a resistor.

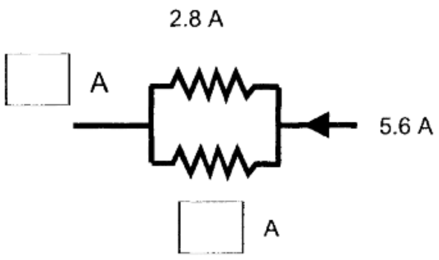
Learning Activity 3.13 (continued)

3. a. As you observed the bulbs when they are connected in series and parallel, in which of the two types of circuits were the bulbs the brightest?
   b. Which of the two types of circuits allowed the largest voltage across the light bulbs?
   c. Compare the voltage and current distribution for two resistors connected in series and then in parallel across the same battery.

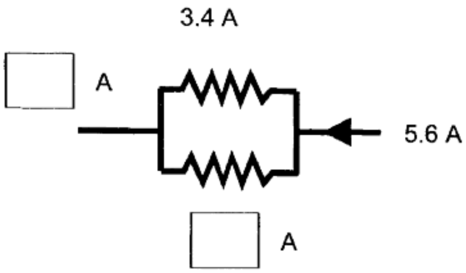
continued

Learning Activity 3.13 (continued)

4. Fill in the boxes with the value for the current flowing through the circuit at that point. Show your work.



5. Fill in the boxes with the appropriate value for current.



Explain why the current through the two resistors is no longer the same value.

6. Draw two circuits described below using schematic diagrams.
   a. A battery made of two cells placed in series is connected to two light bulbs connected in parallel.
   b. A battery made of two cells placed in parallel is connected to three light bulbs connected in series.

Check the answer key.

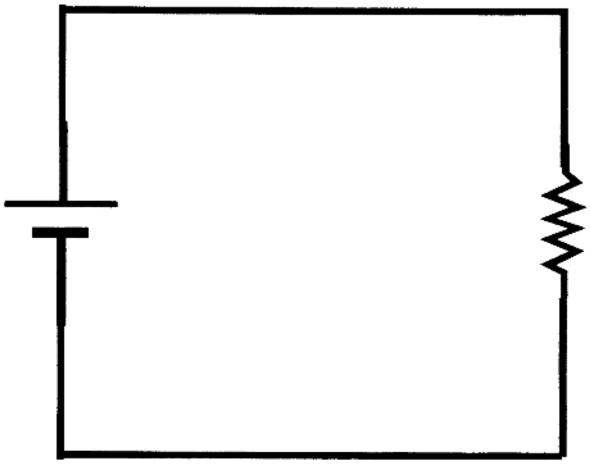
Summary

- The greater the current, the brighter the glow of a bulb.
- Current is conserved in all circuits.
- Current is determined by the resistance. Higher resistance means smaller current; lower resistance means larger current.
- Resistors and appliances can be connected in series and parallel. Resistors follow the same rules as cells for current and voltage.
- Two resistors in series create a larger resistance than one.
- Two resistors in parallel create a smaller resistance than one.
- When resistors are in series, all current must flow through each resistor. When resistors are in parallel, current splits at junctions. In this way, part of the current goes through each resistor. The sum of the current going through each branch in parallel equals the total current in the circuit.
- When resistors are in series, the total potential is equal to the sum of potentials across each resistor. When resistors are in parallel, the potential across each resistor is the same.
- Circuits can be drawn in schematic or representational form. Schematic diagrams are more common.
- Potential drops across a resistor and voltage are the same measurement.

Notes

Assignment 3.4: Circuits Review (23 marks)

1. Use the diagram below to answer the following questions.



a. Label the positive and negative electrodes on the cell above. *(1 mark)*

b. What is this cell called? *(1 mark)*

c. If 6 joules of energy are needed to move 4 coulombs of charge, what is the potential difference across the electrodes in the cell? *(2 marks)*

d. If 4 coulombs of electric charge take 8 seconds to travel through the resistor, what is the ammeter reading in the circuit? *(2 marks)*

2. Indicate whether you would connect cells in series or parallel to do the following: *(2 marks)*
   a. increase current ________________________________
   b. increase voltage ________________________________

3. a. What is a short circuit? *(1 mark)*

   ____
   ____
   ____

   b. Why is a short circuit considered dangerous? *(1 mark)*

   ____
   ____
   ____

4. What are the components of a simple circuit? *(3 marks)*

   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____
   ____

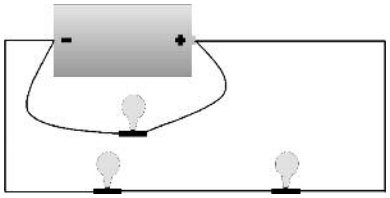
5. Are charges used up in the production of light in a light bulb? *(2 marks)*

   ____
   ____
   ____
   ____
   ____
   ____

6. When you turn the tap on at home, the water comes out of the tap immediately, that is, you do not have to wait for it to flow down from the water tower. Explain. *(2 marks)*

7. Why do the bulbs in the circuits come on instantaneously when you complete the circuit? *(2 marks)*

8. Draw a schematic for the following circuit. *(4 marks)*



Notes

LESSON 12: SIMPLE CIRCUITS LAB

Lesson Focus

After completing this lesson, you will be able to

☐ connect a dry cell, wire, and bulb (load) to produce a practical circuit

☐ determine amount of current qualitatively (without numbers) by comparing the brightness of bulbs

☐ properly connect a voltmeter and an ammeter in a circuit

☐ measure current and voltage using an ammeter and voltmeter

☐ describe the effect that changing the number of cells has on current in bulb(s)

☐ describe the effect that changing the cells to series and parallel combinations has on the current in the bulb(s)

☐ describe the effect that changing the number of bulbs in series or parallel combinations has on current in the bulbs

☐ draw schematics for a variety of cell/bulb combinations

Remember that a voltmeter must be connected in parallel with a cell or resistor in a circuit. To connect a voltmeter in parallel, make certain it is connected to both ends of the cell or resistor. An ammeter must be connected in series with the circuit. This means the ammeter should be a part of the circuit connected in the same way as a resistor. It would be a great idea for you to talk to a teacher or an electrician/electrical technologist who could explain the operation of a voltmeter and ammeter to you. Perhaps the person you contact would help you with the lab and explain any part of this lesson that might be confusing to you.

Notes

Assignment 3.5: Simple Circuits Lab (28 marks)

A learning partner may help you in Option 2 of this assignment.

There are two options for this assignment:

Option 1:

This option requires access to the Internet to use the *Crocodile Clips* software found at www.yenka.com/en/Free_student_home_licences/. You can simulate the circuits shown in the diagrams using this software.

Option 2:

You will need the following materials:

- 2 D cell batteries
- insulated copper wire
- transparent tape to attach the wire to the batteries and bulbs
- 2 small direct current bulbs (flashlight bulbs)

D cell batteries and flashlight bulbs can be purchased from hardware stores. Use any copper wire as your conducting material to connect the batteries and bulbs. Carefully peel away some of the outside insulator from the wire so that you can make a good connection. You can use tape to attach the wire to the batteries and bulbs.

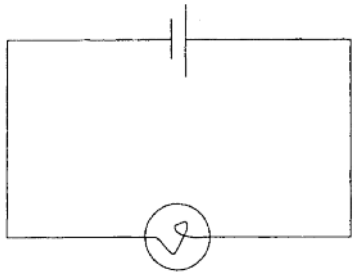
Build the following circuits one at a time. Record your observations of the brightness of the bulb and the current through the bulb. Use Circuit #1 as your standard, and indicate in the chart provided whether Circuits 2 to 8 have

- bulbs that are brighter, dimmer, or the same as Circuit #1's light bulb
- a current that is the same, less than, or greater than Circuit #1

Additionally, you will answer questions for Circuits 3, 4, 7, and 8.

Circuit #1

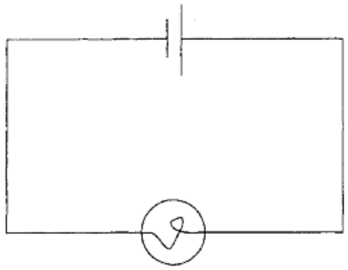
1. Build the following circuit.



Compare to Circuit #1 *(14 marks)*		
	Brightness	**Current**
Circuit 2.		
Circuit 3.		
Circuit 4.		
Circuit 5.		
Circuit 6.		
Circuit 7.		
Circuit 8.		

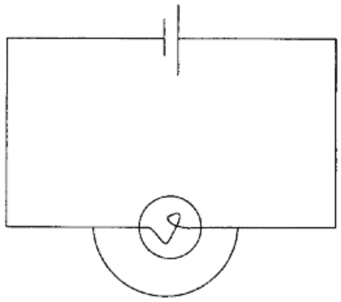
Circuit #2

2. Reverse the direction of the current in Circuit #1. Compare your results to Circuit #1 by filling in the appropriate spaces in your chart.



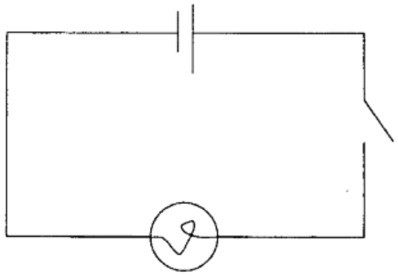
Circuit #3: Short Circuit

3. Connect a wire across the terminals of the bulb. Compare the results to Circuit #1 by filling in the appropriate spaces in your chart. What happens to the light? *(1 mark)*



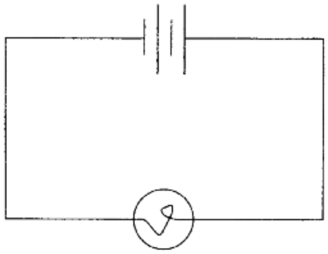
Circuit #4: Simple Circuit (Switched)

4. Add a switch to your circuit, as shown below. Compare the results to Circuit #1 by filling in the appropriate spaces in your chart. When does the light go off? Explain. *(1 mark)*



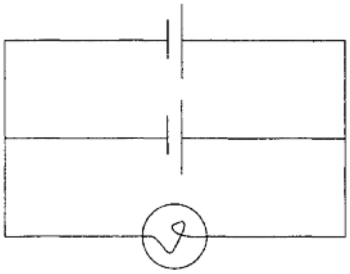
Circuit #5: Cells in Series

5. Add another cell in series to your circuit, as shown below. Compare to Circuit #1, filling in the appropriate spaces in your chart.



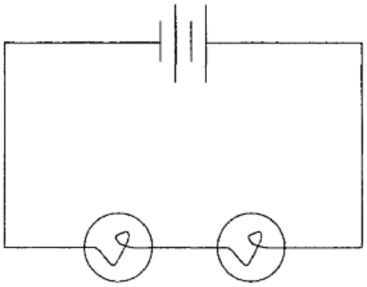
Circuit #6: Cells in Parallel

6. Connect your cells in parallel, as shown below. Compare to Circuit #1, filling in the appropriate spaces in your chart.



Circuit #7: Resistors in Series

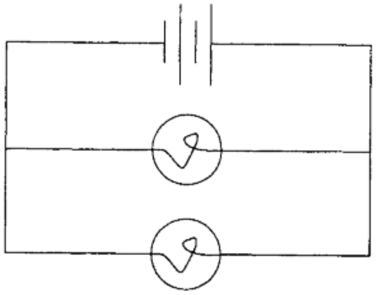
7. a. Make the following circuit and compare it to Circuit #1. Explain your observations in terms of the resistance of the circuit, brightness of the bulbs, and the current delivered to each bulb. *(2 marks)*



b. Unscrew one of the bulbs. Explain what happens. *(2 marks)*

Circuit #8: Resistors in Parallel

8. a. Make the following circuit and compare it to Circuit #1. Explain your observations in terms of resistance of the circuit, brightness of the bulbs, and the current delivered to each bulb. *(2 marks)*



b. Unscrew one of the bulbs. Explain what happens. *(2 marks)*

9. Review the results in your chart. Describe how current changes when
   a. voltage (number of cells) increases but resistance (number of light bulbs) remains the same *(2 marks)*

   ____

   ____

   ____

   ____

   ____

   ____

   b. voltage (number of cells) remains the same but resistance (number of light bulbs) increases *(2 marks)*

   ____

   ____

   ____

   ____

   ____

   ____

Notes

Lesson 13: Using Electricity Safely

Lesson Focus

After completing this lesson, you will be able to

- ☐ demonstrate an understanding of electrical safety in the home
- ☐ describe some methods of electric conservation in the home
- ☐ describe and explain the function of circuit breakers, plugs, fuses, ground wire, neutral wire, and live wire
- ☐ describe a short circuit
- ☐ explain why a short circuit is dangerous, and how household circuits guard against them

Key Words

- direct current
- alternating current
- hertz
- circuit breakers
- short circuit
- overload
- fuse
- ground wire
- ground fault circuit interrupters (GFCI)

Electricity in Your Home

All but the most remote homes in Canada are connected to a source of electricity. Electricity has been a great benefit to homes and industry for many years. We owe Michael Faraday thanks for discovering the relationship between electricity and magnetism that provided the basic tools for constructing electric generators. Electricity is sometimes taken for granted, and as a result of this familiarity, people can become careless. Safe use of household electricity is important as a severe electric shock can be fatal and improper use of electricity can cause house fires.

Household Circuits

Household circuits are similar to the circuits you studied with batteries, but there are differences. Differences include the following:

- Alternating current is used instead of **direct current (DC)**. **Alternating current (AC)** travels in one direction and then reverses to travel in the opposite direction. This complete cycle takes place 60 times every second. We can say the frequency of the current in our system is 60 cycles per second or 60 hertz.

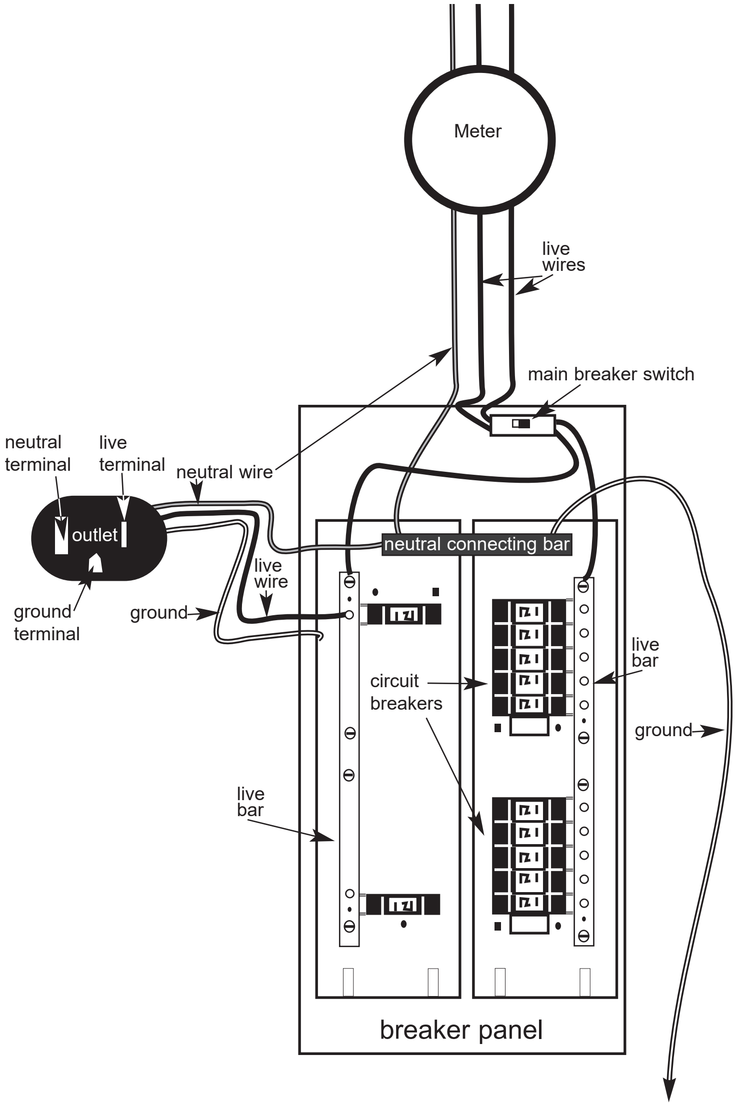
  A **hertz** is a unit used to express how many times a repetitive action takes place in a second. If you were able to crack and eat two sunflower seeds per second, we would say you ate sunflowers at a rate (frequency) of two hertz.

- Household circuits operate at higher voltages. There are three wires that bring electricity into a home. A neutral wire is attached to the ground. Two hot wires (also called live wires) carry 120 volts each. The hot wires form a potential difference of 120 volts each with the neutral wire. When there are two hot wires connected to the dwelling, the household circuits are allowed to operate at either 120 volts or 240 volts.

Household circuits usually use 120 volts of energy and 15 amps of current. A circuit such as this supplies current to several bedrooms. Larger appliances, such as electric stoves and clothes dryers, require more energy. These appliances use 240 volts of energy and up to 50 amps of current.

All circuits are connected to a service panel in the home that supplies electricity to them. You may have noticed that the service panel in your home has many wires entering it. The wires attached to the service panel form the circuits.

Household Electrical—Incoming Wiring, Panel, and One Circuit



Circuit Breakers

The service panel is covered with small toggle switches called circuit breakers. Circuit breakers are safety devices used to open a circuit and stop the current flow if there is a short circuit or a circuit overload.

Short Circuit

A short circuit occurs when a conductor allows current to pass without going through the appliance or lightbulb. The lesser resistance of the conductor allows large amounts of current to travel through that branch and, as a result, the conductor heats up. When the conductor heats up, it can cause a fire if the circuit breakers are not operating.

Overload

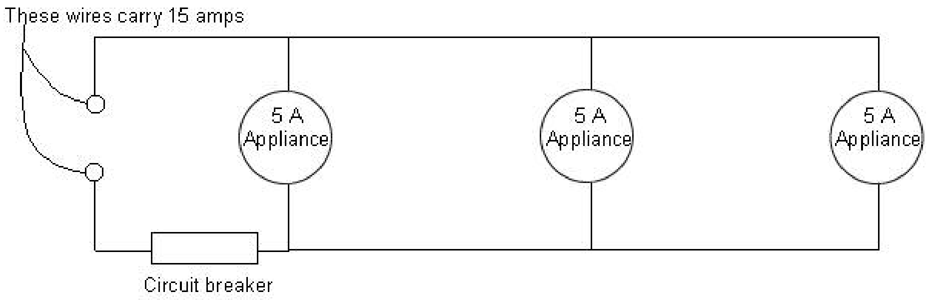
An overload occurs when there are too many appliances attached to a single outlet. In this case, the circuit breaker in the service panel flips off, opens the circuit, and no more current flows.

Fuses

Some appliances also have fuses (e.g., stoves and electronic equipment). A fuse is located at a point where all the current must pass through, usually at the entry point of the current into the appliance. As the current passes through the fuse, it must pass through an easily melted metal. If the current travelling through the fuse reaches a value that is unsafe, the metal melts and the circuit is opened.

Parallel Circuits

The outlets in a house circuit are connected in parallel. A group of parallel resistors always receive the same amount of voltage. By connecting outlets in parallel, all the appliances receive 120 volts on a typical circuit. Each appliance requires current to operate. In a typical household parallel connection, the current requirements of each appliance add up to 15 amps.



Since a typical circuit has a 15 amp circuit breaker, users must be careful that the total current of the appliances does not exceed 15 amps. Electrical contractors are careful to set up circuits that, when used in an ordinary way, would not have current requirements of more than 30 amps. If you used a power bar, for example, and loaded appliances on it, then probably the 15 amp limit would be exceeded. A power overload would result and the circuit breaker would flip off.

Parallel circuits also mean you are able to turn off a single appliance without affecting any other appliances. You will recall that in series circuits, all the current travels through each of the resistors. If the circuit is opened anywhere, none of the resistors receive any current and all the lights stop working. As you can see, series circuits do not function well as household circuits.

Basic House Circuit

A house circuit contains wires that are hot, neutral, and grounded. Look at the diagram at the beginning of the lesson to observe the three wires connected to the outlet.

Each outlet and light bulb is connected to a hot wire and a neutral wire. As you can see from the diagram, each branch in the circuit is connected to a hot wire and a neutral wire, leaving a 120 volt potential across each of the branches. The third connection in an outlet is the **ground wire** that connects the outlet to the ground electrically. The ground terminal on an outlet plug prevents the possibility of a lethal current travelling through your body. The third terminal on an outlet plug is good insurance against accidental shock and should never be removed.

Electrical Safety in the Home

The following list contains some suggestions to raise your awareness of the safe use of electricity in the home. This safety checklist includes

- checking cords on appliances to make certain they are not frayed or loose
- inserting plastic safety plugs in the outlets (if there are small children in the home)
- not overloading extension cords and power bars
- finding the cause before you reset the breaker if a circuit breaker trips
- being extra cautious when using electrical appliances near water or outdoors (Most water is a conductor of electricity because of dissolved minerals. Bathrooms are places where **ground fault circuit interrupters [GFCI]** should be used. A GFCI circuit breaker detects any leaking of current outside the circuit and will break the circuit if, for example, you are in danger of being electrocuted.)
- avoiding doing electrical repairs unless you know what you are doing
- never working on or adjusting any appliance or tool without disconnecting it first
- never removing the ground prong on a three-pronged plug or using three wire extension cords with a three-prong plug
- keeping metal ladders away from power lines
- not using light bulbs with a higher power than the one designed for the fixture

Learning Activity 3.14: Electrical System

This assignment should be done with **extreme care** and in the presence of an adult who knows something about household electricity.

You have spent some time reading about household circuits in this lesson. This is a good time to take a look at an actual service panel, electrical supply, and breakers

1. Go with an adult to inspect the electrical system in your house or apartment. Open the panel door. Look at the service panel, circuit breakers, and wires connected to the panel. Do not remove the panel cover. Draw a picture of the panel interior, indicating
   a. where the electric stove, water heater, and dryer are connected
   b. how many breakers are needed for each circuit
   c. where the main breaker and the main wire connecting your house to the main supply of electricity are located
2. a. You have decided to make some toast for breakfast. What voltage does a toaster use?
   b. The toaster is on a standard household circuit. What can you say about the maximum current passing through the toaster?
   c. Why does the toaster element get hot?
3. Why are two wires needed to run a 240-volt electric stove?
4. What is the purpose of the service panel?
5. What two dangerous situations does a circuit breaker guard against?
6. Name the three wires used in a wall outlet.
7. Why would you put a GFCI circuit breaker in the bathroom?

Check the answer key.

Summary

- There are two hot lines coming into every house or apartment. Each hot line carries 120 volts. Any circuit can be either 120 volts if one of the hot lines is used or 240 volts if both of the hot lines are used.
- Each 120-volt circuit in a house usually has a maximum of 15 amps. Each appliance in the circuit is connected in parallel, so every appliance has a voltage of 120 volts. Since they are connected in parallel, each appliance uses part of the 15 amp maximum. Each circuit should be designed so that, at maximum use, there is no more than a 15-amp current being used.
- Household circuits work on the same principles as battery circuits except they have higher voltages and use alternating current operating at 60 Hz (hertz).
- Short circuits and overloaded circuits can occur. When this happens, circuit breakers and fuses protect against overheated circuits or damage to appliances.
- Electrical safety in the home is extremely important.

LESSON 14: POWER AND ENERGY IN THE HOME

Lesson Focus

After completing this lesson, you will be able to

☐ relate work, energy, and power

☐ calculate electric power, energy, and cost for electric energy in the home

Key Words

- power
- work
- watts
- energy
- joule

Power

Power is the amount of work done per second or the amount of energy used per second. It measures the rate at which work is produced, absorbed, or transferred.

$$\text{Power (watts)} = \frac{\text{Energy (joules)}}{\text{time (seconds)}}$$

When energy is measured in joules and time in seconds, power is measured in joules per second or **watts (W)**.

As an example of how power is measured, picture two students travelling up the same hill. They both reach the top of the hill, so they have the same increase in potential energy. The second student, however, reached the top in less time than the other. This person did the same amount of work or gained the same potential energy in less time and, as a result, he or she used more power.

Electric Energy—Review

It takes some work to create an electric current. You identified the concept of a volt in Lesson 8 as one joule of work done on one coulomb of charge.

$$\Delta V = \frac{\Delta E}{Q}$$

The delta (Δ) symbol means "change in."

The formula can be written in words as:

$$\text{Change in electrical potential (volts)} = \frac{\text{total energy change for all electric charges}}{\text{number of coulombs}}$$

By rearranging the formula, you can calculate the total amount of energy used by an individual appliance or by a whole circuit.

E = VQ

E = total work done on the charge in joules

V = voltage in joules per coulomb

Q = amount of charge in coulombs

Example

A 120-volt electric circuit in a house moved 10 coulombs of electric charge. How much energy is used by the circuit?

E = VQ

Given Information: V = 120 volts, Q = 10 C

E = 120 V x 10 C

= 1200 joules

The circuit required 1200 joules of energy.

Electric Power

Power is defined as the **amount of work done or energy used per second**. The unit of power is called a watt after James Watt who was largely responsible for developing the concept of power.

$$\text{Power}=\frac{\text{Energy}}{\text{time}}$$

$$P=\frac{E}{t}$$

P = power in watts (W)

E = work (energy) in joules

t = time in seconds

Example

An electric hair dryer is rated to use 180 000 joules of electric energy. A teen uses the dryer for 4 minutes to blow dry her hair. What electrical power is needed to run the dryer?

$$P=\frac{E}{t}$$

E = 180 000 j

t = 4 minutes (but we need time in seconds for the formula)

1 minute = 60 seconds

4 minutes = 4 x 60 seconds

= 240 seconds

$$P=\frac{180\ 000\ \text{j}}{240\ \text{s}}$$

= 750 W (watts)

750 watts of power are required to run the dryer for four minutes.

It is possible to substitute current and voltage to produce another formula for determining electric power.

The two formulas below can be used to modify the power formula.

$E = VQ$

$$I=\frac{Q}{t}$$

$$P=\frac{E}{t}$$

Substitute VQ for E from the equation above.

With VQ substituted for E, the formula has changed to the one shown below.

$$\boxed{P=\frac{VQ}{t}}$$

P = power in watts (W)
V = potential in volts (V)
Q = amount of charge in coulombs (C)
t = time in seconds (S)

But

$$I=\frac{Q}{t}$$

We can substitute I for $\frac{Q}{t}$ in the formula above

Now the power formula will look like the one below:

$$\boxed{P = IV}$$

P = power in watts (W)
I = current in amperes (A)
V = potential in volts (V)

Example

How much power is needed to operate an electric car warmer that requires a current of 8 A (amperes) at a voltage of 120 volts?

P = IV

I = 8A, V = 120 V

P = 8A x 120V

= 8 x 120 V

= 960 W (watts)

960 watts of power are required to operate the car warmer.

Electric Energy in the Home

When electricity is used in the home, the company supplying the electricity must be paid. Manitoba Hydro charges each household for the amount of electric energy used. You have seen that electric energy is equal to power x time.

Electric energy = power x time

E = Pt

But we know that power is equal to current x voltage

P = IV

We can combine the formulas to write:

$\boxed{\mathbf{E = IVt}}$ (Electric energy = current x voltage x time)

When Manitoba Hydro sells electric energy, it uses the following formula.

$$\boxed{\text{Cost} = \frac{\text{Power (watts) x time (hours) x unit price}}{1{,}000}}$$

The power formula that you use can be either one of the formulas developed above.

Example

A 1500-watt car heater is used 4 hours a night for 16 days one month. If electric energy were being sold for 11 cents per kilowatt hour, what is the cost of using the car heater?

$$\text{Cost} = \frac{\text{Power (watts) x time (hours) x unit price}}{1{,}000}$$

If you are given time in seconds, then convert to hours by dividing 3600 into the number of seconds since there are 3600 seconds in one hour.

Power = 1500 watts

Time = 4 hours x 16 days

= 64 hours

Unit price = $.11 per hour

$$\text{Cost} = \frac{1500\text{W x } 64\text{H x } \$.11}{1{,}000}$$

Cost = $10.56

The cost of using the car heater is $10.56.

Learning Activity 3.15: Energy and Power

Show your work and answer in complete sentences.

1. An electric circuit used 120 volts to move 2 coulombs of electric charge. What is the energy required by the circuit?
2. An electric stove element is able to convert all of the electric energy it receives into heat energy. The potential across the element is 240 volts and there are 360 coulombs of electric charge going through the stove. How much heat energy in joules is given off by the stove?
3. An electric motor uses 120 volts of energy at 3.2 amps of current.
   a. What power does the motor develop?
   b. What energy is used by the motor over one hour of use? Calculate the answer in joules.
   c. Calculate the cost of using the motor over one hour if the cost per kilowatt hour (kWh) is $0.11.
4. The electric stove from question 2 was used for 90 seconds. What power in watts did the stove use?
5. A girl guide decided to use her flashlight on a camping trip. She placed four new cells in the flashlight by following the directions in the flashlight. The directions showed the positive electrode of one cell touching the negative electrode of the next cell. The dry cells produce a potential of 1.5 volts and a current of 0.5 amperes each.
   a. What name is given to the way the cells are connected?
   b. What is the total current and potential voltage produced by the battery in the flashlight? Explain how you know this.
   c. What power can the battery produce when the flashlight is turned on?
6. A 60-watt light bulb operates on a 120-volt line. How much energy will the bulb use in one hour?

continued

Learning Activity 3.15 (continued)

7. A 120-volt line produces 8 coulombs of electricity in 2 seconds at an appliance.
   a. What is the current through the appliance?
   b. What power does the appliance use?

Check the answer key.

Summary

Electrical terms are used to explain how we use electricity. Power tells us the rate at which energy is being used. We purchase electric energy from the electricity utility company. The electricity utility company calculates the cost of the energy and we receive the bill on the basis of our electric energy use.

Lesson 15: Conserving Energy in the Home

Lesson Focus

After completing this lesson, you will be able to

- ☐ calculate electric power, energy, and cost for electric energy in the home
- ☐ describe some methods of electricity conservation in the home
- ☐ interpret Energuide labels and determine the efficiency of the appliance
- ☐ calculate personal energy use for a day and consider possible methods for energy reduction
- ☐ interpret a monthly Manitoba Hydro bill
- ☐ identify practices of inefficiency in the home
- ☐ propose ways to improve efficiency of electric energy use in the home
- ☐ read and interpret a kilowatt-hour dial electricity meter

Key Words

- efficiency
- light energy
- Energuide label
- resource management
- hydro bill

Efficiency

All electrical devices convert electric energy into other forms of energy. An ordinary incandescent light bulb, for example, converts electric energy to light energy. In the process of converting electric energy to **light energy**, however, much of the electric energy is also used in producing heat energy. In fact, only about 5 percent of the electric energy is actually changed to light energy in the light bulb. In this case, the light bulb is 5 percent efficient.

How to Calculate the Efficiency of Any Electrical Device

Efficiency is calculated by determining the electric energy (or power) put into the appliance and dividing it into the converted energy (or power) output from the appliance. If efficiency is to be expressed as a percentage, multiply the fraction by 100%.

Example

An electric car heater uses 1200 watts of power at 120 volts. The heater is able to produce 360 watts of heat power. What is the efficiency of the heater?

$$\begin{aligned}\text{efficiency} &= \frac{\text{useful energy (power) from the device}}{\text{energy (power) put into the device}}\\ &= \frac{360\text{ W}}{1200\text{ W}}\\ &= 0.3\end{aligned}$$

For every watt of electric power put into the heater, 0.3 watts of heat power are produced.

To determine the efficiency as a percentage, multiply by 100.

$$\begin{aligned}\text{efficiency} &= 0.3 \times 100\%\\ &= 30\%\end{aligned}$$

Incandescent light bulbs are inefficient because they produce only a small amount of the desired energy (light) and a large amount of an undesired energy (heat). A fluorescent bulb is much more efficient because most of the energy conversion is from electric energy to light energy. Very little heat energy is created in a fluorescent bulb.

Learning Activity 3.16: Determining Efficiency

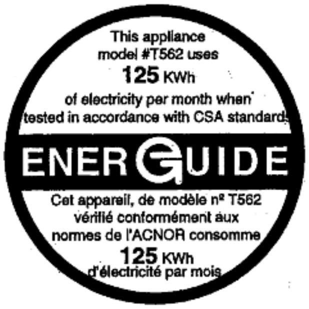
1. Inspect appliances to determine their highest efficiency rating. Make a list of five appliances in which efficiency is a consideration in their purchase. Include in the list what aspects of the appliance to check for when making a purchase.
2. A popcorn popper uses 250 watts of power at 120 volts. The popper is able to produce 80 watts of heat power. What is the efficiency of the heater?

Check the answer key.

Interpreting Energuide Labels

The electrical appliance industry uses a system called **Energuide labels** that give the consumer some idea of the efficiency of an appliance. When purchasing an appliance, use the Energuide label to determine the most efficient use of electrical energy. The Energuide label shows the amount of energy used by the appliance in typical use over a period of a month. This means no calculations are needed; all you do is compare numbers on the label for the same type of appliance and the lowest number is the most efficient. An Energuide label is shown below.

This kind of label should be on any major appliance that consumers purchase to help them comparison shop and make selections.



This appliance
model #T562 uses
125 KWh
of electricity per month when
tested in accordance with CSA standards

ENERGUIDE

Cet appareil, de modèle nº T562
vérifié conformément aux
normes de l'ACNOR consomme
125 KWh
d'électricité par mois

This Energuide label tells the consumer that the appliance will use 125 kWh (kilowatt hours) of electricity per month with normal use.

Personal Energy Consumption

Using energy is a personal responsibility. As individuals, the needs of Manitobans have an impact on whether a new hydroelectric dam will be constructed in the province. By controlling or even reducing the use of electric energy through careful management of this resource in homes and businesses, everyone contributes to good resource management at a provincial level.

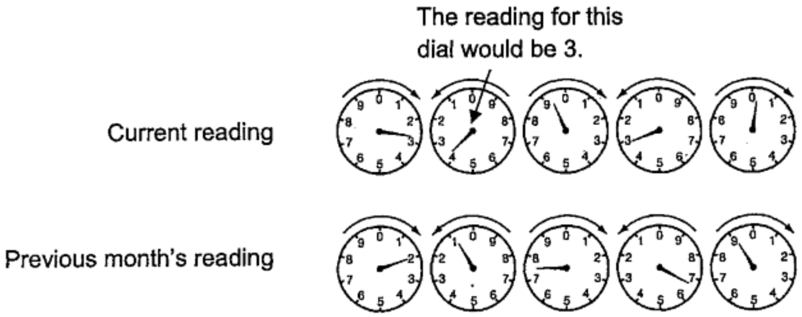
Reading a Hydro Meter

A hydro meter has five dials which give us a five-digit number. The farthest right dial gives the ones digit, the next dial to the right gives us the tens digit, and so on.

The top set of dials gives a reading of 23 930 units at the end of the current month and the bottom meter is the reading of 20 769 units for the previous month. *Notice that the lowest number on the side of the arrow is read*. A different reading is taken every one or two months. The two readings below could have been taken on separate months.

When we purchase electric energy, the difference between the two numbers tells us the amount of energy used. The consumer or the meter reader records the new meter reading and the electricity utility company subtracts the previous reading from the new one and determines the amount of electric energy used. The consumer in this example would have used

  23 930 units (kWh)
–20 769 units (kWh)
   3 161 units of electric energy (kWh)



Interpreting a Hydro Bill

Households that use electricity as a utility will receive a hydro bill based on energy consumption. Part of being a knowledgeable citizen involves interpreting your hydro bill so you know your resource consumption. Interpreting a hydro bill can also help determine the cause of increased consumption and perhaps even contribute to better resource use by helping reduce energy consumption.

Find a household hydro bill. (A sample bill is available online at www.hydro.mb.ca/mybill/sample_bill.pdf.)* Notice whether or not the type of heat is electric. The bill is determined by subtracting the readings between the two dates. What is the reading of the first date? the second date? Subtracting the two readings yields what energy consumption (in kilowatts)?

The bill may be split into two levels of energy use, with a different cost for each level.

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* If you do not have Internet access and cannot find a bill, contact your tutor/marker.

Learning Activity 3.17: Energy Consumption

Answer the following questions based on meter readings and a bill (include a copy of the bill you use) from Manitoba Hydro.

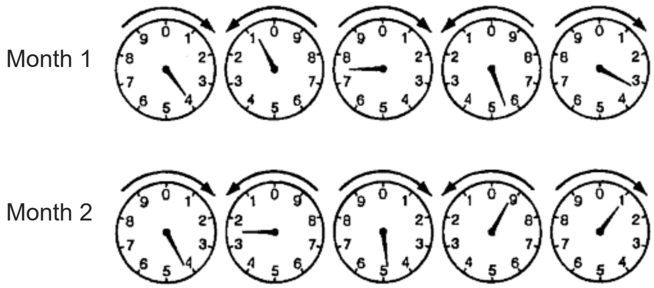
Show your work and answer in complete sentences.

1. A 240-volt electric water heater uses an average of 4800 watts over a period of four hours in one day.
    a. What is the energy consumption for the day (joules and kWh)?
    b. If energy costs are $0.11 per kilowatt hour, what is the cost of operating the heater for the day?

continued

Learning Activity 3.17 (continued)

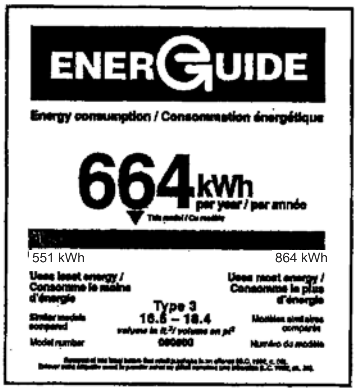
2. Use the diagram of the two meter readings below to answer the questions.



    a. What is the reading for each of the months represented in the diagram above?
    b. How much electrical energy was consumed according to the readings?

3. Use the Energuide sticker below to answer the questions.

    a. How much energy would you expect to use in a year with this appliance?
    b. What is the lowest and highest energy consumption for this type of appliance?
    c. If the electricity you used cost 4.7 cents per kWh, what is the average cost per month when using this appliance?



4. As you review your list of electric energy consumption, name ways that your use of electric energy could be modified to reduce consumption.

    a.

    b.

    c.

continued

Learning Activity 3.17 (continued)

5. Use a hydro bill[*] to answer the following questions.
   a. What is the total amount of energy consumed by this customer?
   b. What is the total cost of energy before taxes for the customer?

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[*] A sample bill is available online at www.hydro.mb.ca/mybill/sample_bill.pdf. If you cannot find a hydro bill, contact your tutor/marker.

Check the answer key.

Summary

- You pay for the electric energy use by the kilowatt hour (kWh).
- Electrical efficiency is a term used to show how well the appliance converts electric energy to some other form of useful energy. An efficiency rating of 87 percent for a motor indicates that a motor is able to take 87 percent of the electric energy it receives and change it to mechanical energy. The remaining 13 percent of the electric energy is changed into heat.
- Energuide labels allow consumers to determine which appliances are most energy efficient. It also allows the consumer to estimate the cost of using the appliance.
- Hydroelectric bills are part of a consumer's financial responsibility. As responsible consumers, it is important to be able to interpret hydroelectric bills.
- Manitobans have a personal responsibility to assess energy use and to reduce excessive use.

Notes

Assignment 3.6: Electricity Project (15 marks)

For your final assignment in this module, you will complete one of three options. Read over each project carefully, and then make your decision. Marking rubrics for each option are located at the end of the project descriptions.

Option 1: Nuclear Power Options in Canada

We are living in times where the potential environmental and climate consequences of human activities are in very sharp focus. It is now accepted as reasonably certain that our human imprint on the planet—particularly related to the burning of fossil fuels such as coal, petroleum products, and natural gas—can be measured. We can be confident that the planet's balances are changing because of our influence, but we don't know how this rapid change will play out over the next few centuries. You may not be aware that important decisions need to be made about where we will get the "big energy" required in the future to improve the quality of life in many countries of the world, while at the same time reduce inputs into the natural and human environments such as "greenhouse gas" emissions (GHGs).

In this assignment option, you will have an opportunity to explore an important part of Canada's energy mix—and that is **nuclear power** generation. Right now, about 15 percent of Canada's total electric energy generation is already being produced from a number of nuclear power plants that have been built in provinces such as New Brunswick and Ontario. In France, over 80 percent of its electricity needs are being met using the nuclear power option.

And it is more than just electricity—Canada is one of the world's leading suppliers of what are called "medical isotopes." These are radioactive materials that are produced in Canadian facilities to be used around the world in treating cancers in people and in other medical applications. Pretty exciting stuff from the invisible world of the tiny atom!

Here's a possible plan for Option 1:

Exploring:

Visit the website of the **Canadian Nuclear Association** at www.cna.ca/curriculum/cna_nuc_tech/introduction-eng.asp?pid=Introduction and look at the section entitled "Nuclear Technology at Work." At that page, you can explore a number of applications of nuclear technology such as the following:

- Electricity Generation
- Medical Applications
- Uranium Exploration and Mining
- Commercial and Manufacturing Applications
- Inspection and Monitoring Services
- Scientific Research
- Aeronautics and Space Exploration
- Food and Agriculture

Planning and Creating:

You are the science advisor and public relations coordinator for an organization that is committed to the peaceful uses of nuclear power and nuclear materials of many kinds. Recent data shows that the Manitoba public knows very little about the fields related to nuclear technologies, and you believe that it is important for them to be more informed about their energy options and the other real and possible uses of nuclear materials. You would like to create a multimedia demonstration (slide presentation, blog site, podcast, etc.) or perhaps a printed brochure that will flex your artistic and scientific thinking. The product you provide will highlight the application of nuclear materials in one of the categories that you have selected from the "Exploration" stage that you have just completed.

Among the items that could appear in your information, the following may be very important:

a. Is this about nuclear technology itself, a medical application, a commercial application, or is it related to aerospace technologies?

b. What role has Canada served in this nuclear application?

c. Is it possible that Manitoba could develop a future in this area of nuclear technology?

d. How does the nuclear technology you have explored affect the natural environment? Is it a "cleaner" or "greener" way of doing things?

e. Do we know how we will dispose of the radioactive materials in a safe and responsible manner after we have made use of them?

Option 2: Electricity Audit at Home

Do an electric energy audit of your home each day for two weeks (14 days). An audit can be performed by reading the meter at the same time each day. Record the day, meter reading, and anything you feel would affect energy use that day. You might include the weather and daily activities.

Determine what day the most energy is used in your home, and identify the appliance(s) that might be responsible for higher energy consumption.

Describe how you and your family members might reduce energy consumption, and provide a brief, point-by-point action plan that could be put into place after a family meeting.

Option 3: Alternative Fuel Vehicles

Automobiles have been major contributors to environmental pollution. Electric cars, hydrogen-powered vehicles, or hybrid-electric cars seem to provide an answer to our concerns about pollution and the production of greenhouse gases (GHGs) from burning fossil fuels. One method of electric energy production comes from a technology such as fuel cells. Fuel cell–driven cars are seen by many as the answer to putting "clean cars" on our roads.

In this option, imagine that you are the science and technology writer for a local radio station or newspaper. Write a lead story of at least 350 words on the use of alternative-fuelled cars. In your reporting, include how the technology works as an alternative to gasoline-powered vehicles. Include diagrams to help your description. Use the rest of your report to explore the importance of the impact on society that a move to electricity-driven vehicles may have. You might consider such possibilities as cost and pollution involved in the production of the new type of car, whether we can deliver the energy and power demands required for different transportation needs, and whether these new technologies are actually "pollution free." You are writing for an audience that knows very little about this, so keep the science at a level that a 12-year-old might enjoy reading!

Assignment 3.6: Electricity Project Marking Rubric

Grading Rubric for Assignment 3.6/Option 1	**Nuclear Power Options in Canada**	**15 marks**
Student has clearly identified which section of the assigned website will provide the basis of the project. /2 marks	2 marks:	Student has identified the component of the Canadian Nuclear Association website (www.cna.ca) and provided a few details as to why this section looked interesting.
	1 mark:	Student has identified the component of the Canadian Nuclear Association website (www.cna.ca) only with no further details.
	0 marks:	Very little or no information is included.
Student has identified their project area of interest as a medical application, a commercial application, aerospace technology, or the workings of a nuclear plant itself. /2 marks	2 marks:	Student provides some explanation of the applications of nuclear materials to their chosen project.
	1 mark:	Student provides a very brief explanation of the applications of nuclear materials to their chosen project.
	0 marks:	Very little or no information is included.
Student determines the potential roles that Canada and/or Manitoba can play in the future of nuclear energy. /2 marks	2 marks:	Student provides some explanation of the potential roles that Canada and/or Manitoba can play in the future of nuclear energy.
	1 mark:	Student provides a very brief explanation of the potential roles that Canada and/or Manitoba can play in the future of nuclear energy.
	0 marks:	Very little or no information is included.
Student identifies, with some details, how this particular nuclear technology is a “cleaner” way of doing things in the environment. /4 marks	4 marks:	Student identifies, with at least four details, how this particular nuclear technology is a “cleaner” way of doing things in the environment.
	2 mark:	Student identifies, with at least two details, how this particular nuclear technology is a “cleaner” way of doing things in the environment.
	0 marks:	Very little or no information is included.
Presentation of the final project /5 marks	5 marks:	The project (whether it be a brochure, web page, online blog set up, .ppt, etc.) demonstrates superior ability to communicate ideas and concepts related to nuclear energy (or materials use) using balanced views, is easy to follow, is stimulating, and is free of errors.
	3 marks:	The project (whether it be a brochure, web page, online blog set up, .ppt, etc.) demonstrates minimum expectations for communicating ideas and concepts related to nuclear energy (or materials use) using balanced views, is easy to follow, is stimulating, and is free of errors.
	0 marks:	Communication of ideas is ineffective.

Assignment 3.6: Electricity Project Marking Rubric (continued)

Grading Rubric for Assignment 3.6/Option 2		Electricity Audit at Home 15 marks
Student records the day and electricity meter reading for 14 days. /5 marks	5 marks:	The day and electricity meter reading was recorded for 14 days in a clear and concise manner, in language suitable for the audience.
	3 marks:	The day and electricity meter reading was recorded for less than 14 days in a clear and concise manner.
	2 marks:	The day and electricity meter reading was recorded for 7 days with the information presented in a manner that is sometimes unclear.
	0 marks:	Very little or no information is included.
Student records daily situations (such as weather) that may affect the consumption of electricity. /4 marks	4 marks:	At least 2 activities (or one activity repeated on at least 2 separate occasions) likely to affect the consumption of electricity is included. Information is presented in a clear and concise manner, in language suitable for the audience.
	2 marks:	One activity likely to affect the consumption of electricity is included. Information is presented in a clear and concise manner, in language suitable for the audience.
	0 marks:	Very little or no information is included.
Student determines which day has the highest energy consumption. /2 marks	2 marks:	The day which has the highest energy consumption is identified.
	0 marks:	The day which has the highest energy consumption is not identified.
Student identifies which appliance(s) is responsible for higher energy consumption. /2 marks	2 marks:	An appliance likely to be responsible for higher energy consumption is identified.
	0 marks:	No appliance is identified.
Student gives suggestions for reducing energy consumption. /2 marks	2 marks:	Two comprehensive suggestions for reducing energy consumption are included in a clear and concise manner, in language suitable for the audience.
	0 marks:	No suggestions are included.

Assignment 3.6: Electricity Project Marking Rubric (continued)

Grading Rubric for Assignment 3.6/Option 3	**Alternative Fuel Vehicles**	**15 marks**
Essay Content		**/11 marks**
Student provides a written description of how the alternative technology works. /5 marks	5 marks:	All of the major components of the propulsion system, their various functions, and the way these interact with each other are described in a clear and concise manner.
	4 marks:	Most of the major components of the propulsion system, their various functions, and the way these interact are described in a clear and concise manner.
	3 marks:	Most of the major components of the propulsion system, their various functions, and the way these interact are described in a generally clear and concise manner.
	2 marks:	Some of the major components of the propulsion system, their various functions, and the way these interact are described in a generally clear and concise manner.
	1 mark:	Some of the major components of the propulsion system, their various functions, and the way these interact are described in a generally unclear, rambling, or stilted manner.
	0 marks:	Very little or no information is included.
Student provides a diagram of how the alternative technology works. /3 marks	3 marks:	The diagram includes all of the major components. Each part is clearly labelled.
	2 marks:	The diagram includes most of the major components. Each part is clearly labelled.
	1 mark:	The diagram includes a few of the major components. The parts are not clearly labelled.
	0 marks:	Very little or no information is included.
Student provides a clear description of society's expectations of this new propulsion technology. /3 marks	3 marks:	All required information is included, and information is presented in a clear and concise manner, in language suitable for the audience.
	2 marks:	Most required information is included, and information is presented in a clear and concise manner, in language suitable for the audience.
	1 mark:	Major pieces of information are missing. Information is sometimes unclear.
	0 marks:	Very little or no information is included.

Assignment 3.6: Electricity Project Marking Rubric (continued)

Grading Rubric for Assignment 3.6/Option 3	**Alternative Fuel Vehicles**	**15 marks**
Presentation		**/4 marks**
The essay: • is clear and easy to follow • is interesting to read /4 marks	4 marks:	The essay is clear, easy to follow, and interesting.
	3 marks:	The essay is clear, with few errors in spelling and grammar. It requires further editing and organization of thought.
	2 marks:	The essay is unclear or hard to follow in places. It may contain some errors in spelling and grammar.
	0 marks:	The essay is generally unclear and very difficult to follow. It contains a significant number of errors in spelling and grammar.

Notes

LESSON 16: ELECTRICITY REVIEW

Lesson Focus

This lesson contains a review learning activity that you can use to test your knowledge of the concepts within this module.

Learning Activity 3.18: Electricity Review

Matching

Match the following terms with the description at the right. Place the letter for the proper description in the space at the left of the term.

___ Faraday

___ ammeter

___ rate of flow

___ open circuit

___ power

___ coulomb

___ wet cell

___ photoelectric

___ Energuide

___ electroscope

a. detects the presence of an electrostatic charge on an object
b. will not allow an electric current to flow
c. provides consumers with an estimation of the energy used in their appliance
d. converts light energy into electrical energy
e. discovered that a conductor moving through a magnetic field will produce electricity
f. voltaic cell
g. measures electric current
h. coulombs/second
i. joules/second
j. a specific number of electric charges

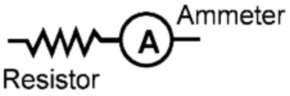
Multiple Choice

Circle the choice that best matches the question.

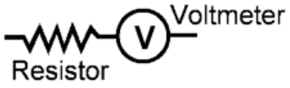
1. A negatively charged rod is placed close to a pith ball. The pith ball is attracted to the charged rod, touches it, and then is repelled by the charged rod.
   a. The pith ball was neutral initially and became positively charged.
   b. The pith ball was positively charged initially and became neutral.
   c. The pith ball was negatively charged initially and stayed negatively charged.
   d. The pith ball was neutral initially and then became negatively charged.
2. You would not place a copper tube on a metallic stand when charging it electrostatically with a piece of plastic because
   a. the copper tube would not allow any charge to be placed on it
   b. the copper tube would be grounded and lose its charge
   c. the charge would not distribute evenly over the copper tube
   d. the charge on the copper tube would be dangerously large
3. A negatively charged rod touches an electroscope.
   a. Negative charges move into the electroscope.
   b. Positive charges move into the electroscope.
   c. Negative charges move out of the electroscope.
   d. Positive charges move out of the electroscope.
4. If you attach an ammeter to a circuit, you measure
   a. power
   b. potential
   c. rate of flow of charge
   d. rate of energy consumption

5. You want to measure the electric potential across a resistor. Which of the setups below would you choose to find the potential?

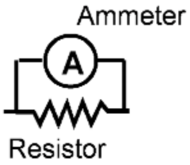
a.



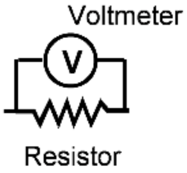
b.



c.



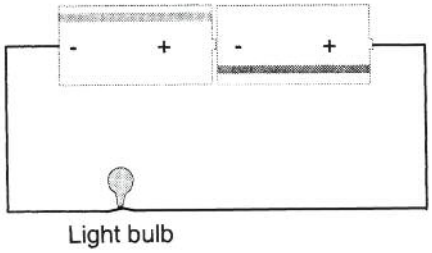
d.



6. Six coulombs of electric charge travels through a resistor which uses 12 joules of energy. What is the potential difference across the resistor?
   a. 72 J/C
   b. 12 J/C
   c. 2 J/C
   d. 18 J/C

7. A basic circuit consists of
   a. a load
   b. a source of electrical energy
   c. a conducting loop
   d. all of the above

8.



In the diagram at the left, each cell is capable of producing an electric potential of 1.5 volts. What is the potential delivered to the light bulb?

   a. 1.5 volts
   b. 3.0 volts
   c. 0 volts
   d. either (a) or (b)

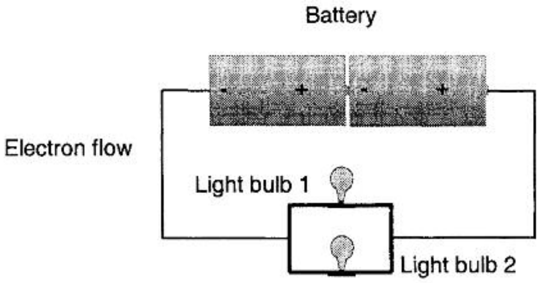
9. An electric current
   a. is a flow of positive charges through a metallic conductor
   b. is the rate of flow of positive and negative charges in an ionic solution
   c. is measured in watts
   d. can only be measured on open circuit

Fill In the Blanks

1. An object that is positively charged must have _________________ some electrons.
2. _________________ developed a model for electrostatic charge called the one-fluid model.
3. A car temperature gauge makes use of an electric current created from a _________________.
4. Electrical power is measured in _________________.
5. When two electrodes are placed in an electrolytic solution, attached to a load, and an electric current is produced, the cell is called a _________________.
6. Whenever there is a junction in a circuit, we can say the resistors are connected in _________________. (series, parallel)
7. A dry cell and an electrostatically charged rod are the same in that they and _________________.
8. Using electricity _________________ around our homes is important.

Short Answer

1. Answer the questions based on the diagram below.

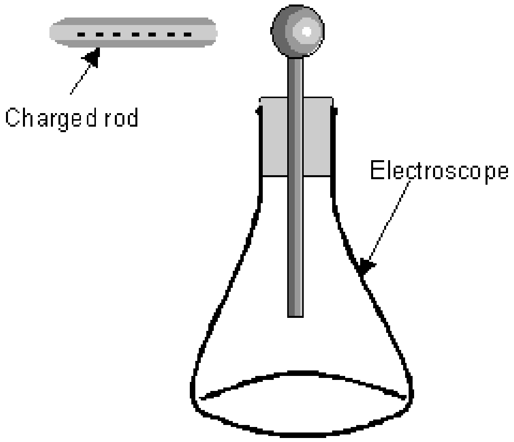


   a. Draw the schematic diagram for the pictorial diagram shown.
   b. Draw the directions of electron flow on the diagram beside the appropriate labels.

2. Why would a manufacturer of electric stoves use nichrome wire in the heating element and copper wire everywhere else?
3. Name three ways that you could conserve electricity in your home.

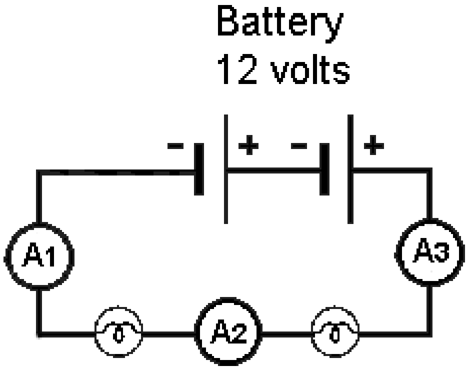
4. The electroscope is electrically neutral before the charged rod is brought close.

   Draw the leaves on the electroscope for the conditions shown and describe the movement of charge that takes place as the charged rod is brought close to but doesn't touch the electroscope. There is no ground.



Problems

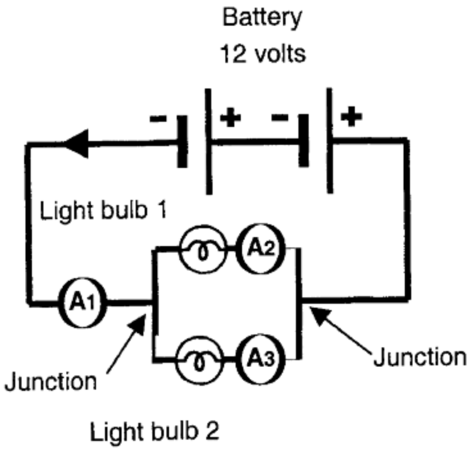
1. The reading in A1 is 1 ampere.



   a. What is the reading in A2?
   b. What is the total current in the circuit?
   c. Are the two light bulbs connected in series or parallel?
   d. The two light bulbs have the same resistance. What is the voltage across each of the light bulbs?
   e. How much power does one light bulb use?

2. Do the following problems.
    a. In an electric circuit, 24 coulombs of electric charge pass a point in the circuit, every two seconds. Calculate the electric current travelling through the circuit.
    b. In the same circuit, it takes 12 volts to move the 24 coulombs of electric charge. How much energy, in joules, is used to move the electric charge?
3. Use the diagram below to answer the following questions.

    The reading in A1 is 1 ampere.



    a. If the two lamps have the same resistance, what are the readings for

        A2?

        A3?
    b. What is the voltage across light bulb 1?
4. A current of 3 amperes travels through a resistor and there is a potential of 12 volts across the resistor.
    a. Calculate the power supplied to the resistor.
    b. What electrical energy is used by the resistor over five seconds?

5. Use the Energuide symbol below to answer the following questions.

This appliance
model # 1234567890 uses
123 kWh
of electricity per month when
tested in accordance with CSA standards.

ENERGUIDE

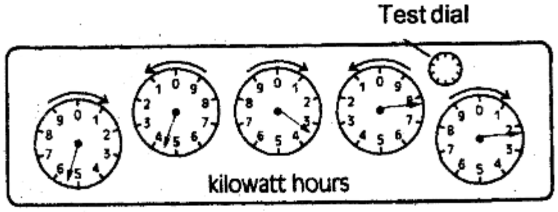
Cet appareil, de modèle nº 1234567890
vérifié conformément aux
normes de l'ACNOR, consomme
123 kWh
d'électricité par mois.

   a. How much energy would be used by this appliance in a typical month of use?

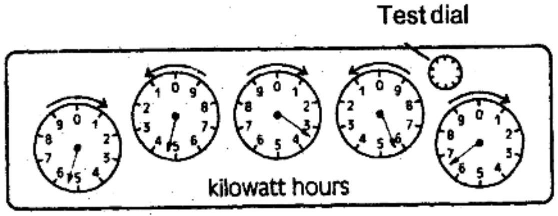
   b. If you were paying 7.5 cents per kWh for electrical energy in your area, what would it have cost to use this appliance for a month?

6. How many kilowatt hours has the consumer used between readings as shown in the two diagrams below?

Reading Day 2



Reading Day 1



Check the answer key.

Notes

MODULE 3 SUMMARY

Congratulations! You have finished the third module of Grade 9 Science.

Submitting Your Assignments

It is now time for you to submit Assignments 3.1 to 3.6 to the Distance Learning Unit so that you can receive some feedback on how you are doing in this course. Remember that you must submit all the assignments in this course before you can receive your credit.

Make sure you have completed all parts of your Module 3 assignments and organize your material in the following order:

- Module 3 Cover Sheet (found at the end of the course Introduction)
- Assignment 3.1: Understanding Electricity
- Assignment 3.2: Create Your Own Electroscope
- Assignment 3.3: Producing Electricity
- Assignment 3.4: Circuits Review
- Assignment 3.5: Simple Circuits Lab
- Assignment 3.6: Electricity Project

For instructions on submitting your assignments, refer to How to Submit Assignments in the course Introduction.

When you complete all four modules of this course, you will write your final examination. Instructions for arranging to write your final examination and information regarding the final practice examination can be found in the Introduction and at the end of Module 4.

Notes

MODULE 3

Learning Activity Answer Key

MODULE 3
LEARNING ACTIVITY ANSWER KEY

LESSON 1

Learning Activity 3.1: Home Experiment

1. **Student answers will vary.**
2. Scatter small pieces of paper on a table. Rub a plastic straw with the wool and bring the straw near the bits of paper. Record what you observed below.

   The plastic straw becomes charged when rubbed. The paper bits are attracted to the plastic straw. After touching the straw the paper bits may be pushed away (repelled) from the straw. The straw has gained something when it was rubbed with wool; this "something" is called a charge.
3. Find two materials at home to replace the plastic straw and wool that demonstrate the same effects. Try a toothbrush, pen, or CD jewel case. Rub them with cotton or silk material.
4. Stick a piece of transparent tape about 30 centimetres long on a table (base tape). Take a second piece about 10 centimetres long and make a tab by folding the first centimetre of tape. Stick this tape to the base tape and press it down well with your finger. Now peel the short tape briskly from the base tape. Bring the tape near the paper bits. What can you conclude about the tape?

   The piece of tape has become "charged." It attracts the bits of paper.
5. Make another 10-centimetre strip as before. Press them both down on the base tape and then peel them both away together. Peel the tapes from one another. What happens when you bring the tapes near each other?

   The two pieces of tape attract each other.
6. Stick the tapes to the edge of the table, call them tape "T" to indicate the top tape when they are peeled apart, tape "B" to indicate the bottom tape when they are peeled apart. Make another pair of tapes as you did in step 4 and also call them "T" and "B" tapes. Bring each tape, one at a time, near the tapes on the edge of the table. Summarize your results. Include responses to the following in your summary:

a. What happens to the tapes as you bring them close?

	T	B
T	Repel	Attract
B	Attract	Repel

T. This tape repels tape “T” on the table and attracts tape “B” on the table.

B. This tape attracts tape “T” on the table and repels tape “B” on the table.

b. How many different charges can be identified?

There are two different charges: positive and negative.

c. Outline a simple rule to describe how different charges affect each other.

Like (the same) charges repel each other, unlike (different) charges attract.

7. Now bring each tape near the paper bits.

a. What happens?

The paper is attracted by tape “T” and by tape “B.” After being attracted some of the paper bits are repelled by the tape.

b. What charge is on the paper bits?

The paper bits are neutral before touching the charged tape. The paper bits that have touched the charged tape gain a charge from the tape. The charge on the paper bits and the charge on the tape will be the same.

c. How do the paper bits affect each other?

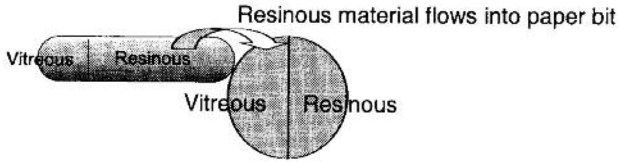
The bits of paper have no effect on each other before being attracted to the tapes. After being attracted to a tapes, the paper bits can also gain a charge and repel each other since they all have the same charge.

The paper bits from the different tapes will attract each other in the same way the two tapes attracted each other.

8. Use the two-fluid and one-fluid models to explain the results of the experiment with the cloth and straw. Can these two models adequately explain your observations?

Two-Fluid Model

When the straw is rubbed with the wool, some of the resinous material in the wool is transferred to the straw. This leaves an excess of resinous material in the straw and an excess of vitreous material in the wool. The two have opposite amounts of resinous and vitreous material. When the resinous straw is brought close to the neutral paper, the vitreous part of the paper is attracted to the straw. If the paper is brought near the vitreous wool, the resinous part of the paper is attracted to the wool.



The two-fluid model has no difficulty in explaining what happened.

One-Fluid Model

If the wool and straw are rubbed together, some of the electric fluid is transferred to the straw, leaving an excess on the straw and a reduction in the fluid on the wool. The paper is attracted to either the wool or the straw because the paper will either give off electric fluid or receive electric fluid, depending on the situation. The same reasoning could be used to explain the transparent tape experiment.

The two-fluid model had no difficulty in explaining what happened.

Both fluid models adequately explain the attraction of the cloth and straw. The reason for rejecting the fluid models must lie deeper within the atom.

An answer for the question above would be evaluated according to the following:

- Part mark for stating that both models can explain the behaviour of paper bits when touching a charged straw.
- Medium mark for partial explanation of how resinous and vitreous charge or electric fluid can affect paper bits.
- Full marks for full explanation of resinous and vitreous charge or electric fluid and how they affect paper bits when in contact with a charged straw.

LESSON 2

Learning Activity 3.2: Charging by Friction

1. Why is it dangerous to golf during a thunderstorm?

   Lightning, which is a giant electric charge, can easily travel through the metal golf clubs into your body, and into the ground through metal golf cleats. You become badly burned or electrocuted in the process.

2. When wool rubs a plastic straw, where do the extra negative charges on the plastic straw come from?

   The extra negative charges come from the wool.

3. Explain how the glass rod could receive a positive charge.

   The glass rod gave some of its negative charges to the silk.

4. Would the glass tubing attract or repel the paper bits?

   The tubing would attract the neutral paper bits.

Learning Activity 3.3: Charging by Conduction

1. Draw a diagram to show what happened when the foam bit approached the copper tubing. Be sure to indicate the electrical charge on each object.

   The negatively charged foam bit will be repelled by the negatively charged copper tubing.

LESSON 3

Learning Activity 3.4: Electron Model of Electricity

1. What kind of charge is on an object that has an excess of electrons?

   The object is negatively charged when it has an excess of electrons.

2. If an object loses electrons, what is the charge on the object?

   If an object loses electrons, it becomes positively charged.

3. What can be said about the number of positive and negative charges on a neutral object?

   A neutral object has an equal number of positive and negative charges.

4. Explain your answer in question 3.

   Atoms, under ordinary conditions, are neutral electrostatically. Each atom will have an equal number of protons and electrons. The negative charges from the electrons will cancel out the positive charges from the protons in the atom.

5. Why is it that electrons always move and protons do not when a solid object is charged?

   Electrons move when a solid object is charged because they are loosely held by the atom. Protons, on the other hand, are much more strongly bound to the atom in a cluster at the centre of the atom in an area called the nucleus and, therefore, do not move.

6. Why would it be a waste of time to hold a copper tube in your hand and try to charge it by rubbing it with a cloth?

   Holding a conductor in your hand while charging it by friction is a waste of time because any charge created on the conductor would travel to your hand and be grounded. The result is a constantly grounded object that can never store a charge. This is why we charge insulators by friction.

7. a. What charge will move in the apparatus below?

      Electrons (negative charges) will move.

   b. What direction will the charge move in the apparatus below?

      The electrons move from the charged rod into the conductor.

   c. After the charged rod is removed from contact with the conductor, what is the charge left on

      i. the conductor?

         A negative charge is left on the conductor when the charged rod is removed.

ii. the rod?

A negative charge still remains on the rod because a charge balance occurs between the rod and the conductor before all the negative charges are drained from the charged rod.

d. What name is given to this method of charging an object?

The conductor was charged by contact or conduction.

8. A cotton cloth is used to create a charge on a piece of acetate.

a. What charge is left on the acetate?

The acetate is left with a positive charge.

b. What is the charge left on the cotton cloth?

The cotton cloth is left with a positive charge.

c. Explain your answers to parts (a) and (b) above.

Because the cloth wipes electrons off the acetate, the acetate is left with a positive charge. The cotton has an excess of electrons and gains a negative charge.

9. Describe the process of charging by contact.

An object is charged by contact when it accepts electrons from a second object by direct touch. The object becomes negatively charged, while the object losing electrons becomes positively charged.

10. a. What makes a material a good conductor?

A good conductor has electrons that can easily move from one nucleus to another and will transfer between atoms. Metals are examples of good conductors.

b. What makes a material a good insulator?

A good insulator has electrons that are strongly attracted to their particular nucleus and that will not transfer between atoms. Glass and plastics are examples of good insulators.

11. Using the electron model, explain what is happening in the following diagram at a subatomic level.

The rod is positively charged because it has previously lost electrons. As it nears the conductor, the loosely held electrons in the conductor are attracted to the positively charged rod and gather on the side nearest the rod, making that side negatively charged and the other, electron-poor side positively charged. Because the conductor is mounted atop an insulator, any excess electrons on the conductor cannot escape into the ground.

LESSON 4

Learning Activity 3.5: Static Electricity Model

1. Describe what happens as the charged plastic straw is brought close to the paper bit.

   The paper bit is attracted to the plastic straw.

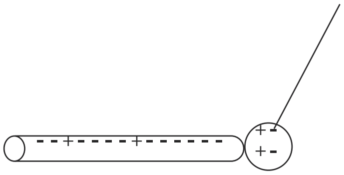
2. Describe what happens after the charged straw touches the paper bit.

   After the paper bit touches the plastic straw, it suddenly jumps away.

3. Explain why this activity demonstrates a discrepant event.

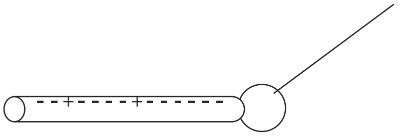
   This activity represents a discrepant event because the paper bit is initially neutral.

4.



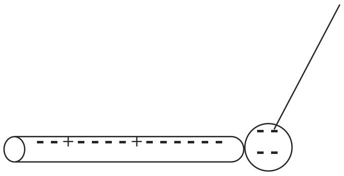
The electrons are repelled to the right side of the paper bit. The left side is left positively charged and is attracted to the negatively charged plastic straw.

5.



The paper bit touches the plastic straw and receives a negative charge by conduction.

6.

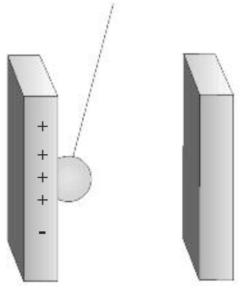


Now the negatively charged paper bit is repelled by the negatively charged plastic straw.

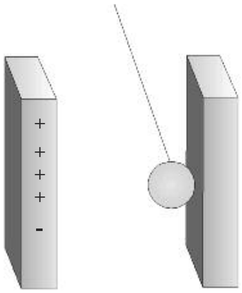
7. Is the electron model for electrostatics able to explain the behaviour of the neutral paper bit when it touches the charged plastic straw?

   Yes, the electron model does explain the behaviour of the paper bit. The charges separate, creating a region of positive charge closer to the negative plastic straw. The negative straw attracts this charge on the paper bit. When the paper bit touches the straw, negatives are transferred to the paper bit and it repels.

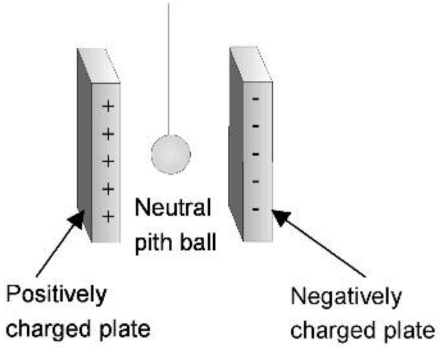
8. a. **The left side of the pith ball becomes more negative and the right side becomes more positive. The pith ball is attracted to the positive plate.**



   b. **Once the pith ball touches the left plate it releases some electrons to the positive plate. Enough electrons leave the pith ball bit to make it positively charged. Since the left plate is positively charged, the pith ball is now repelled by the left plate and attracted to the right plate. The pith ball moves to the right and touches the right plate where it receives electrons and becomes negatively charged.**



c. **The cycle continues to repeat itself until the charge is drained from the plates and the pith ball bit stops moving.**



d. Why will the pith ball eventually stop moving?

The pith ball bit stops moving because the charge is eventually drained from the plates by the moving paper bit.

9. What happens when there are charged particles in a solution?

   Both positive and negative particles can move.

10. **Student answers will vary.**

LESSON 5

Learning Activity 3.6: The Electroscope

1. What happens to the negative charges on the rod as it touches the metal sphere?

   Some of the negative charges on the rod are transferred to the electroscope where they are distributed evenly over all the parts that conduct electricity. These parts are the metal sphere at the top, the metal rod, and the gold foil.

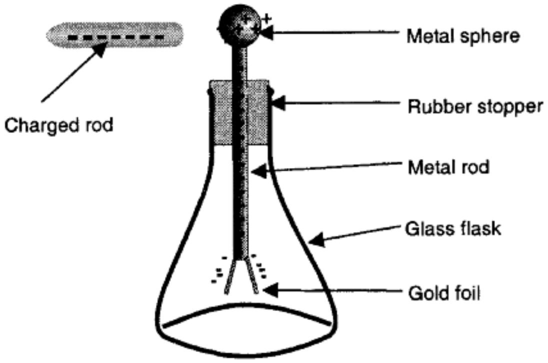
2. The negatively charged rod is removed. What is the charge remaining on the rod?

   When the metal rod is removed, there is still a negative charge on the rod. This is because the rod will transfer negative charges only until the charges balance on the electroscope and the charged rod. This occurs when they both have a negative charge.

3. After the rod is removed, what is the charge left on the electroscope?

   After the rod is removed there is a negative charge left on the electroscope.

4. Show the charge distribution on the electroscope by drawing the charges on the diagram on the previous page. Draw only the excess charge that is left when the charged rod is removed.



5. Why does the charge not travel into the rubber stopper and the glass flask?

   The charge does not travel into the rubber stopper and the glass flask because they are both insulators.

6. What is the charge on the left gold foil? right gold foil?

   The charge on both gold leaves is negative.

7. What will happen to the two pieces of gold foil as a result of the charges on them?

   The two pieces of gold foil repel each other as a result of their having the same charge.

8. Gold foil can be hammered into extremely thin sheets. This makes the sheets of foil very light. Explain why the lightness of the foil is important in an electroscope.

   The electrostatic repulsion between leaves is not strong, so the leaves need to be light so that they lift up when a charge is placed on them.

9. How could you neutralize the electroscope so the two pieces of gold foil will go back to their original position?

   An electroscope can be easily and quickly neutralized by touching the metal knob at the top of the electroscope with your hand. You provide a ground for the electrons to travel into or out of the electroscope and balance the charge on the electroscope.

10. The negatively charged rod is brought close to the metal sphere on the electroscope, but you do not allow it to actually touch.
    a. Describe the movement of charges in the electroscope.

       The electrons move as far away as they can from the leaves.

    b. What happens when the charged rod is removed?

       When the charged rod is removed, the electrons redistribute themselves evenly throughout the electroscope.

LESSON 6

Learning Activity 3.7: The Voltaic Cell

1. What can you say about lemon juice that would explain the production of electricity when copper and zinc are placed in the lemon?

   Lemon juice acts as an acid that reacts with electrodes to produce an electric current.

2. Volta noted that in electrostatics, charges move momentarily and then quickly come to rest, but in an electric circuit using a voltaic cell, charges continue to move for a long time. Describe how you could test Volta's statement to see if it is correct.

   To prove Volta's statement, hold a neon bulb between your fingers and touch an object charged with static electricity. The bulb lights for an instant only. Next, connect a properly rated bulb to a dry cell, and you will see it stays lit for a long time.

3. What are the main parts of any voltaic cell?

   The main parts of any electric cell are two different metal strips placed in an acid or salt solution.

4. How does the voltaic pile demonstrate the main parts of the cell?

   A voltaic pile uses two different metal discs placed on paper discs that are damp with a salt solution. The discs and the damp paper provide the main components of a voltaic cell.

5. Describe how the conditions in which Galvani saw frog legs twitch satisfied the requirements for a voltaic cell.

   The frog legs were placed in two different metals (brass and iron) and the body fluids provided the electrolytes (salt solution).

LESSON 7

Learning Activity 3.8: Dry Cells

1. Name four ways that dry cells are used.
    a. **run watches**
    b. **provide light**
    c. **run toys**
    d. **backup power computers**
2. When sodium chloride is dissolved in water to form the solution for a voltaic cell, an ionic solution is formed.
    a. Write the symbols for the ions and the name of each.

       Na+ Sodium ion

       Cl- Chloride ion
    b. State which ion gains electrons and which loses electrons.

       Sodium gains an electron and chloride loses an electron.
    c. What is the charge left on the copper electrode?

       There is a positive charge left on the copper electrode.

Learning Activity 3.9: Electric Current

1. Electric current is used every day.
    a. What two measurements must be known to calculate electric current?

       Measurement 1—quantity of charge (coulombs)

       Measurement 2—time (seconds)
    b. What are two ways of expressing electric current that you have seen in this lesson?

       i. **Coulombs/second**

       ii. **Amperes**

c. If there were 24 coulombs passing a section of conductor in 1.6 seconds, what is the electric current in the conductor?

I = Q/t

Q = 24 C

t = 1.6 s

I = 24 C/1.6 s

I = 15 C/s or 15 A

d. A hydraulic system pumps 25 litres of oil past a section in the hydraulic line in one hour. What is the rate of flow of the hydraulic oil?

Rate of flow = Quantity/time
= 25 litres/1 hour
= 25 litres/hour

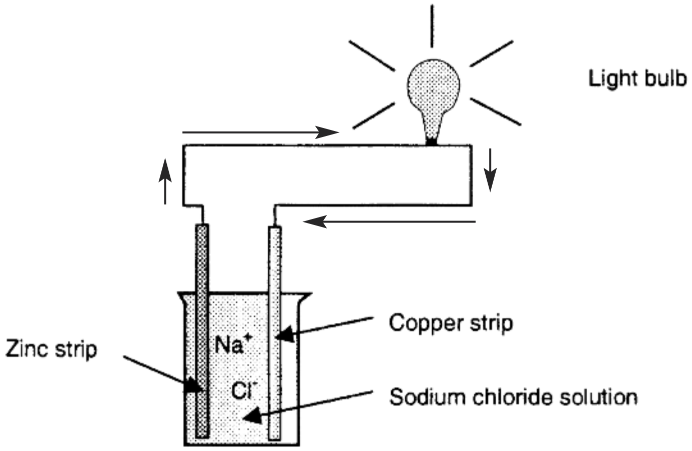
e. You have difficulty sleeping and decide to count sheep. The sheep jump a fence in single file. What is the rate of flow of sheep over the fence if you count 150 in five minutes?

Rate of flow = Quality/time
= 150 sheep/5minutes
= 30 sheep/minute

f. You have made a voltaic cell and connected it to a light bulb. The bulb lights up so you know there is an electric current. What needs to be done to determine a number value for the electric current?

You would need to place an ammeter in the circuit with the light bulb.

2. Use the diagram to answer the following questions.



a. Label the direction of the current flow somewhere on the diagram.

Electron current flow would be from the zinc strip to the bulb and from the bulb to the copper strip as shown on the diagram.

b. What chemical is dissolved in the water?

Sodium chloride or table salt has been dissolved in the water.

c. What happens to the chemical when it is dissolved in the water?

The sodium chloride forms sodium and chloride ions in solution.

d. What name is given to the

Na+ ion?

Na+ = sodium ion

the Cl– ion?

Cl– = chloride ion

e. What happens between the Na+ ion and the copper strip?

The Na+ ion gains an electron from the copper strip.

f. What happens between the Cl– ion and the zinc strip?

The Cl– ion loses an electron to the zinc strip.

g. Which of the two metal strips begins accumulating an excess of electrons?

The zinc strip begins accumulating an excess of electrons.

h. What direction do you predict the electrons will travel on the basis of a buildup of electrons?

The electrons should travel from the electrode which has an excess of electrons to the electrode which has an absence of electrons, that is, from zinc to copper.

i. Does your answer in part (a) agree with your answer in part (h)?

Yes, the answers in part (a) and (h) agree.

j. If you wanted to measure the electric current in the circuit, how do you modify the set-up shown in this question?

To measure electric current in the set-up shown, just place an ammeter in the circuit.

k. What name is given to the type of cell shown in this question?

The cell shown above is called a voltaic cell.

3. The formula for determining current in a circuit is I = Q/T. In the table below, fill in the blank spaces with the appropriate names.

Name	Unit	Abbreviations
Current	***amperes***	***A***
Quality	***coulombs***	***C***
Time	***seconds***	***t***

4. The formula I = Q/T determines the different values for current and even values for quantity and time. Fill in the blank spaces in the table below.

I	***2.5A***	2A	12A	***6A***
Q	5C	6C	***24C***	42C
T	2s	***3s***	2s	7s

LESSON 8

Learning Activity 3.10: Potential Energy

1. An electric cell is able to provide 4 coulombs of electric charge with 8 joules of potential energy to a device in the circuit. What is the voltage of the battery?

   Voltage = Total Energy / coulombs
   Voltage = 8 joules / 4 coulombs
   Voltage = 2 joules/coulomb = 2 volts
   The battery has a voltage of 2 volts.

2. A battery has a potential energy of 1.5 volts. If the battery produced 3 coulombs of electric charge, what is the total work done by the battery?

   Voltage = Work Done / coulombs
   Work Done = Voltage x Coulombs
   Work Done = 1.5 volts x 3 coulombs
   Work done = 4.5 joules
   The battery performs 4.5 joules of work.

LESSON 9

Learning Activity 3.11: Types of Electricity

1. Who discovered the connection between electricity and the moving of a conductor through a magnetic field?

   Faraday discovered the connection between electricity and moving a conductor through a magnetic field.

2. What happens to the current when a bar magnet is pushed into and pulled out of a coil of copper wire?

   When a bar magnet is pushed into and then pulled out of a coil of copper, there is a current travelling one direction and then travelling the opposite direction.

3. Name at least one device that uses the piezoelectric effect to produce a weak electric current.

   A microphone and a telephone receiver can use the piezoelectric effect.

4. Why is a thermocouple an important part of your car?

   The thermocouple allows us to know the temperature of the coolant in the car radiator as we travel down the road.

5. Which of the five different methods of producing electricity described in this lesson is used to provide electric energy for your home?

   Electricity used in our home is produced using electromagnetic induction.

6. How did Faraday design an apparatus to get a constant current?

   Faraday designed an apparatus so that conductors could rotate through the magnet, allowing a large number of conductors per second to travel through the magnet.

LESSON 10

Learning Activity 3.12: Simple Circuits

Locate two cells and a light bulb in a science lab. If you cannot find the cells and a bulb at a school, you can purchase two "D" cells and a small direct current bulb (flashlight bulb) in a hardware store.

1. Use some light gauge wire and connect one cell and one bulb together as shown. Record your observations.

   When connected, the bulb lights up.

2. Connect the cells in series, as shown in the "Cells in Series" diagram earlier in this lesson, and attach them to the bulb. Compare the brightness of the bulb to the one in question 1. Explain.

   The bulb is brighter than in question 1. Cells in series have a voltage equal to the sum of the voltages of the two cells. In this case V = 1.5 + 1.5 = 3.0v. More voltage "pushes" more electrons through the wires and the bulbs, and more energy is delivered to the bulb.

3. Connect the cells in parallel, as shown in the "Cells in Parallel" diagram earlier in this lesson, and attach them to the bulb. Compare the brightness of the bulb to question 1. Explain.

   The bulb is the same brightness as question one. Cells in parallel have a voltage equal to the voltage of one cell. In this case, V = 1.5v. The same amount of current is "pushed" through the bulb and the same amount of energy is delivered to the bulb.

4. Explain the difference in current between the circuit in question 1 and the one in question 3.

   The brightness of the bulbs is the same, but in circuit 1 the current is supplied by one cell. In circuit 3 the current is supplied by two cells. Since each cell provides a proportion of the current, cells in parallel will last longer.

5. Modify the cells and the bulb in question 1 to reverse the connections and change the direction of the current. What effect does this have on the light produced by the bulb?

   The direction of the current in a simple direct current circuit does not matter. Electrons will still be transported from one terminal to another and give up their energy in the resistance of the circuit.

LESSON 11

Learning Activity 3.13: Circuits

1. Are the bulbs the same brightness?

   The bulbs are connected in series so the current through each bulb is the same. Since current determines brightness, the bulbs will all have the same brightness.

2. Modify your series circuit into a parallel circuit as shown in the diagram above. Visually check the brightness of the two bulbs. How does their light compare with the bulb in the series circuit?

   The bulbs are connected in parallel so that the current through each bulb is different. Since current determines brightness, the bulbs will not be as bright as those in the series circuit.

3. a. As you observed the bulbs when they were connected in series and parallel, in which of the two types of circuits were the bulbs the brightest?

   The bulbs were brightest in the series circuit.

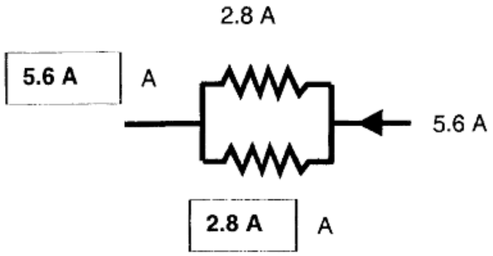
   b. Which of the two types of circuits allowed the largest voltage across the light bulbs?

   The largest voltage occurs when the bulbs are in parallel.

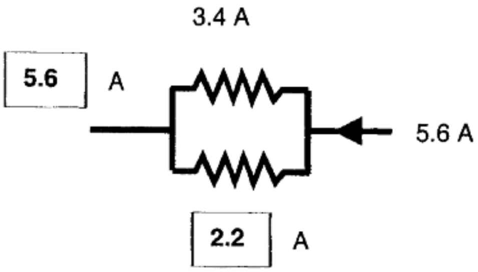
   c. Compare the voltage and current distribution for two resistors connected in series and then in parallel across the same battery.

   Two resistors in series have lower voltage than they would in parallel but they have a larger current.

4. Fill in the boxes with the value for the current flowing through the circuit at that point.



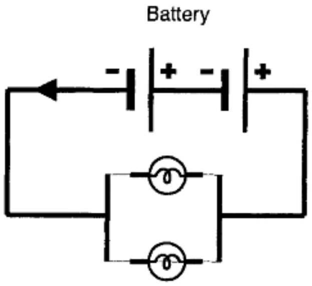
5. Fill in the boxes with the appropriate value for current.



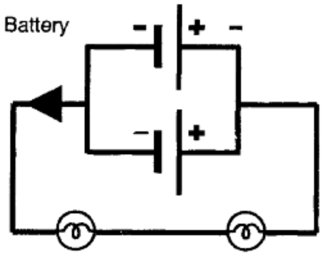
Explain why the current through the two resistors is no longer the same value.

The current through the resistors is no longer the same value since the resistors have a different value for the resistance. Remember that current is determined by resistance.

6. Draw the two circuits described below using schematic diagrams.
   a. A battery made of two cells placed in series is connected to two light bulbs connected in parallel.



   b. A battery made of two cells placed in parallel is connected to three light bulbs connected in series.



LESSON 13

Learning Activity 3.14: Electrical System

1. **Student answers will vary.**
2. a. You have decided to make some toast for breakfast. What is the voltage across the toaster?

   The voltage across the toaster is 120 volts.

   b. The toaster is on a standard household circuit. What can you say about the maximum current passing through the toaster? Explain.

   The maximum current through the toaster is 15 amps. This current is not possible, however, because you wouldn't be able to operate any appliance other than the toaster if that were the case.

   c. Why does the toaster element get hot?

   The toaster element gets hot because the manufacturer deliberately chose a metal conductor with a high resistance for the toaster elements. The high resistance creates a high temperature in the metal conductor.
3. Why are two wires needed to run a 240-volt electric stove?

   Each of the hot wires bringing electricity into the house carries 120 volts. If 240 volts are needed to operate an electric stove then two wires, each carrying 120 volts, are required.
4. What is the purpose of the service panel?

   The service panel is used to direct electricity to the whole house using the appropriate number of 15-amp circuits on 120 volts and 40- or 50-amp circuits at 240 volts. The service panel also contains the circuit breakers needed to prevent short circuits or overload conditions.
5. What two dangerous situations does a circuit breaker guard against?

   A circuit breaker guards against short circuits and overload conditions.
6. Name the three wires used in a wall outlet.

   The three wires used in an outlet are

   - **the hot wire**
   - **the neutral wire**
   - **the ground wire for outlets**

7. Why would you put a GFCI circuit breaker in the bathroom?

   A GFCI circuit breaker should be installed in a bathroom or on an outside outlet because it guards against any current leakage, which is especially important when the person using an appliance is wet or standing in wet conditions.

LESSON 14

Learning Activity 3.15: Energy and Power

1. An electric circuit used 120 volts to move 2 coulombs of electric charge. What is the energy required by the circuit?

   E = VQ

   = 120V x 2C

   = 240 j of energy

   The circuit requires 240 joules of energy.

2. An electric stove element is able to convert all of the electric energy it receives into heat energy. The element voltage is 240 volts and there are 360 coulombs of electric charge going through the stove. How much heat energy in joules is given off by the stove?

   E = VQ

   = 240 V x 360 C

   = 86 400 J

   Since all the electrical energy has been converted to heat energy, the amount of heat energy released from the stove is also 86 400 joules.

3. An electric motor uses 120 volts of energy at 3.2 amps of current.

   a. What power does the motor develop?

      P = IV

      = 3.2 A x 120 volts

      = 384 W

      The motor develops 384 watts of power.

b. What energy is used by the motor over one hour of use? Calculate the answer in joules.

E = Pt

= 384 W x 3600 s

= 1 382 400 J

The motor uses 1 382 400 joules of energy in an hour.

c. Calculate the cost of using the motor over one hour if the cost per kilowatt hour (kWh) is $0.11.

Cost = Cost per kWh x kWh

$$= \$0.11 \times \frac{384\ \mathrm{W}}{1000} \times 1\ \mathrm{h}$$

= $.04 or 4 cents

It costs four cents to run the motor over one hour.

4. The electric stove from question 2 was used for 90 seconds. What power in watts did the stove use?

E = VQ

= 240 V x 360 C

= 86 400j

P = E/t

= 86 400 j/90 s

= 960 W

The stove used 960 watts of power.

5. A girl guide decided to use her flashlight on a camping trip. She placed four new cells in the flashlight by following the directions in the flashlight. The directions showed the positive electrode of one cell touching the negative electrode of the next cell. The dry cells produce a potential of 1.5 volts and a current of 0.5 amperes each.

a. What is the name given to the way the cells are connected?

The cells are connected in series.

b. What is the total current and potential voltage produced by the battery in the flashlight? Explain how you know this.

The total voltage is 6.0 V. When the four cells are connected in series, the total voltage is equal to the sum of voltages of the four cells.

Total current for the four cells is 0.5 amps because connecting cells in series doesn’t change their current.

c. What power can the battery produce when the flashlight is turned on?

P = IV

= 0.5 A x 6.0 V

= 3.0 W

The battery can produce 3 watts of power.

6. A 60-watt light bulb operates on a 120-volt line. How much energy will the bulb use in one hour?

E = Pt

= 60 W x 3600 s (1 hour = 3600 seconds)

= 216 000 j

The bulb will use 216 thousand joules of energy.

7. A 120-volt line produces 8 coulombs of electricity in 2 seconds at an appliance.

a. What is the current through the appliance?

I = Q/t

= 8 C/2 S

= 4 C/s or 4 A (amperes)

The current is 4 amperes.

b. What power does the appliance use?

P = IV

= 4 A x 120 V

= 480 W (watts)

The appliance uses 480 watts of power.

LESSON 15

Learning Activity 3.16: Determining Efficiency

1. **Student answers will vary.**
2. A popcorn popper uses 250 watts of power at 120 volts. The popper is able to produce 80 watts of heat power. What is the efficiency of the heater?

Efficiency = useful energy/total energy x 100%

Efficiency = 80 watts/250 watts x 100%

Efficiency = 0.32 x 100%

Efficiency = 32%

The heater has a 32% efficiency rate.

Learning Activity 3.17: Energy Consumption

1. A 240-volt electric water heater uses an average of 4800 watts over a period of four hours in one day.
   a. What is the energy consumption for the day (joules and kWh)?

      E = Pt

      4 hours = 4 H x 3600 seconds per hour
      = 14 400 s

      E = 4800 W x 14 400 s
      = 69 120 000 joules
      = 6.9 x 10^7 joules

      Calculate energy in joules

      The day's energy consumption was 6.9 x 10^7 joules

      E = Pt

      4800 W = $\frac{4800}{1000}$ = 4.8 kW

      E = 4.8 kW x 4 h
      = 19.2 kWh

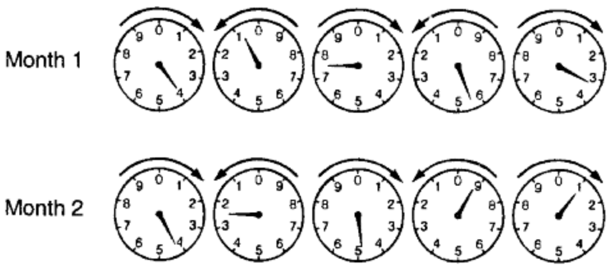
      Calculate energy in kWh

      or 19.2 kilowatt hours.

   b. If energy costs are $0.11 per kilowatt hour, what is the cost of operating the heater for the day?

      Cost = energy (kWh) x cost per kWh
      = 19.2 kWh x $0.11 per kWh
      = $2.11
      It costs $2.11 to operate the heater daily.

2. Use the diagram of the two meter readings below to answer the questions.
   a. What is the reading for each of the months represented in the diagram below?



40 753

42 491

b. How much electrical energy was consumed according to the readings?

Month 2 – Month 1 = 42 491 – 40 753

= 1738 kWh

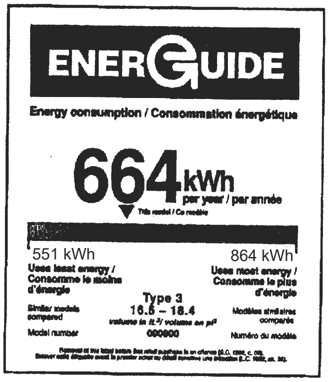
3. Use the Energuide sticker below to answer the questions.

a. How much energy would you expect to use in a year with this appliance?
Normal use would result in 664 kWh of energy.

b. What is the lowest and highest energy consumption for this type of appliance?

Lowest use = 551 kWh

Highest use = 864 kWh



c. If the electricity you used cost 4.7 cents per kWh, what is the average cost per month when using this appliance?

Cost = kWh x unit cost

= 664 kWh x $.047

= $31.21 for one year's use

One month's use would be $\frac{1}{12}$ of a year's use = $31.21/12

= $2.60 per month average cost.

4. As you review your list of electric energy consumption, name ways that your use of electric energy could be modified to reduce consumption.

a. Turn off lights when they are not needed.

b. Reduce use of hot water.

c. Use gas or wood to heat your home.

5. Use the latest hydro bill for your home to answer the following questions.
    a. What is the total amount of energy consumed by this customer?
    Student answers will vary.
    b. What is the total cost of energy before taxes for the customer?
    Student answers will vary.

MODULE 3

Learning Activity 3.18: Electrical Review

Matching

Match the following terms with the description at the right. Place the letter for the proper description in the space at the left of the term.

__**e**__ Faraday
__**g**__ ammeter
__**h**__ rate of flow
__**b**__ open circuit
__**i**__ power
__**j**__ coulomb
__**f**__ wet cell
__**d**__ photoelectric
__**c**__ Energuide
__**a**__ electroscope

a. detects the presence of an electrostatic charge on an object
b. will not allow an electric current to flow
c. provides consumers with an estimation of the energy used in their appliance
d. converts light energy into electrical energy
e. discovered that a conductor moving through a magnetic field will produce electricity
f. voltaic cell
g. measures electric current
h. coulombs/second
i. joules/second
j. a specific number of electric charges

Multiple Choice

Circle the choice that best matches the question.

1. A negatively charged rod is placed close to a pith ball. The pith ball is attracted to the charged rod, touches it, and then is repelled by the charged rod.
   a. The pith ball was neutral initially and became positively charged.
   b. The pith ball was positively charged initially and became neutral.
   c. The pith ball was negatively charged initially and stayed negatively charged.
   d. The pith ball was neutral initially and then became negatively charged.

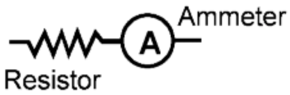
2. You would not place a copper tube on a metallic stand when charging it electrostatically with a piece of plastic because
   a. the copper tube would not allow any charge to be placed on it
   b. the copper tube would be grounded and lose its charge
   c. the charge would not distribute evenly over the copper tube
   d. the charge on the copper tube would be dangerously large

3. A negatively charged rod touches an electroscope.
   a. Negative charges move into the electroscope.
   b. Positive charges move into the electroscope.
   c. Negative charges move out of the electroscope.
   d. Positive charges move out of the electroscope.

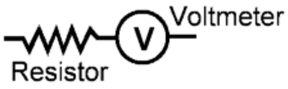
4. If you attach an ammeter to a circuit, you measure
   a. power
   b. potential
   c. rate of flow of charge
   d. rate of energy consumption

5. You want to measure the electric potential across a resistor. Which of the setups below would you choose to find the potential?

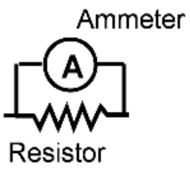
a.



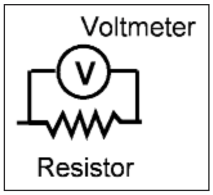
b.



c.

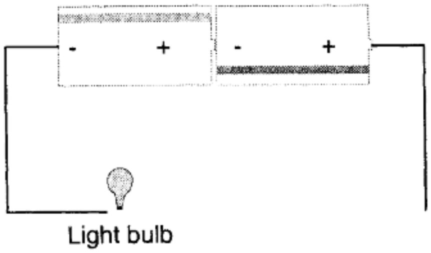


d.



6. Six coulombs of electric charge travels through a resistor which uses 12 joules of energy. What is the potential difference across the resistor?
   a. 72 J/C
   b. 12 J/C
   c. 2 J/C
   d. 18 J/C

7. A basic circuit consists of
   a. a load
   b. a source of electrical energy
   c. a conducting loop
   d. all of the above

8. 

In the diagram at the left, each cell is capable of producing an electric potential of 1.5 volts. What is the potential delivered to the light bulb?

   a. 1.5 volts
   b. 3.0 volts
   c. 0 volts
   d. either (a) or (b)

9. An electric current
   a. is a flow of positive charges through a metallic conductor
   b. is the rate of flow of positive and negative charges in an ionic solution
   c. is measured in watts
   d. can only be measured on open circuit

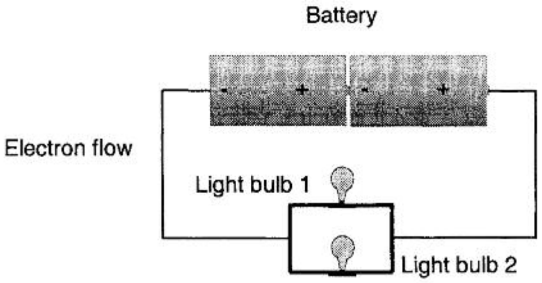
Fill In the Blanks

1. An object that is positively charged must have **lost** some electrons.
2. **Benjamin Franklin** developed a model for electrostatic charge called the one-fluid model.
3. A car temperature gauge makes use of an electric current created from a **thermocouple** source of emf.
4. Electrical power is measured in **watts**.

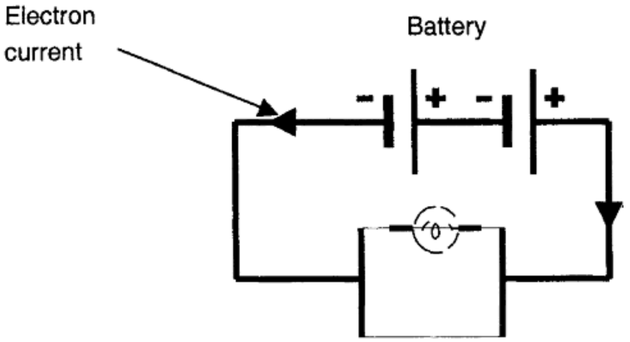
5. When two electrodes are placed in an electrolytic solution, attached to a load, and an electric current is produced, the cell is called a **voltaic (wet)** cell.
6. Whenever there is a junction in a circuit, we can say the resistors are connected in **parallel**. (series, parallel)
7. A dry cell and an electrostatically charged rod are the same in that they **store electric potential** and **make a spark**.
8. Using electricity **safely** around our homes is important.

Short Answer

1. Answer the questions based on the diagram below.



   a. Draw the schematic diagram for the pictorial diagram shown.



   b. Draw the directions of electron flow on the diagram beside the appropriate labels.

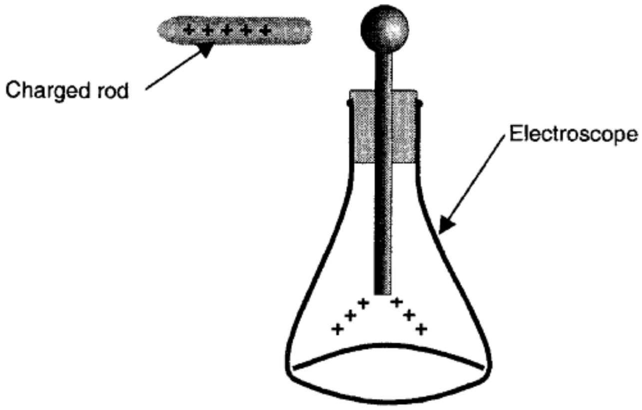
2. Why would a manufacturer of electric stoves use nichrome wire in the heating element and copper wire everywhere else?

   Nichrome wire has high resistance to the flow of electrons. High resistance means heat is produced when a current travels through a conductor. The manufacturer of the electric stove wants heat produced in the stove burners but not anywhere else, so he makes all wiring copper except for the nichrome wire in the burners.

3. Name three ways that you could conserve electricity in your home.
   - **a. Use energy efficient appliances.**
   - **b. Use fluorescent lighting wherever possible.**
   - **c. Use less electrical energy whenever possible (turn off lights when not in use, etc.).**

4. The electroscope is electrically neutral before the charged rod is brought close.

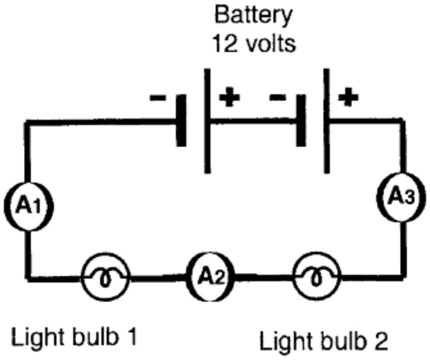
   Draw the leaves on the electroscope for the conditions shown and describe the movement of charge that takes place as the charged rod is brought close to but doesn't touch the electroscope. There is no ground.



Electrons are attracted from the leaves to the sphere of the electroscope. The leaves are left with a positive charge and the sphere has a negative charge. The charge will remain this way until the charged rod is removed.

Problems

1. The reading in A1 is 1 ampere.



   a. What is the reading in A2? **1A**
   b. What is the total current in the circuit? **1A**
   c. Are the two light bulbs connected in series or parallel? **Series**
   d. The two light bulbs have the same resistance. What is the voltage across each of the light bulbs? **6 volts**
   e. How much power does one light bulb use? **P = IV, P = 6 W**

2. Do the following problems.
   a. In an electric circuit, 24 coulombs of electric charge pass a point in the circuit, every two seconds. Calculate the electric current travelling through the circuit.

$Q = 24$ **$I= \frac{Q}{t}$**

$t = 2$ s **$I = 24$ C / 2 s**

$\underline{I = 12\text{ A}}$

   b. In the same circuit, it takes 12 volts to move the 24 coulombs of electric charge. How much energy, in joules, is used to move the electric charge?

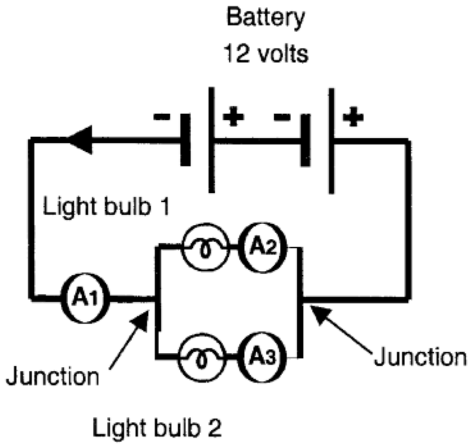
$V = 12$ volts **$V = \frac{E}{Q}$**

$Q = 24$ C **$E = VQ$**

$E = 12\text{ V} \times 24\text{ C}$

$\underline{E = 288\text{ J}}$

3. Use the diagram below to answer the following questions.
   The reading in A1 is 1 ampere.



   a. If the two lamps have the same resistance, what are the readings for
      A2? **0.5 A**
      A3? **0.5 A**
   b. What is the voltage across light bulb 1? **12 V**
4. A current of 3 amperes travels through a resistor and there is a potential of 12 volts across the resistor.
   a. Calculate the power supplied to the resistor.

      I = 3 A
      V = 12 Volts

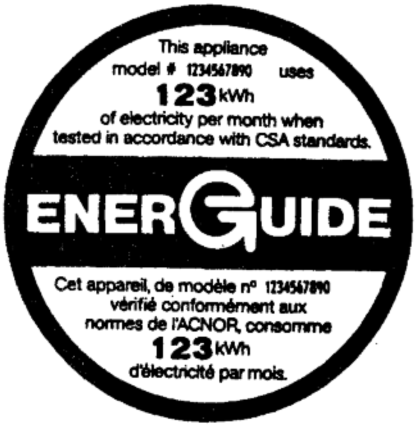
      P = IV
      P = 3 A x 12 V
      P = 36 W

   b. What electrical energy is used by the resistor over five seconds?

      I = 3 A
      V = 12 Volts
      t = 5 s

      E = Ivt
      E = 3 A x 12 V x 5 s
      E = 180 J

5. Use the Energuide symbol below to answer the following questions.



   a. How much energy would be used by this appliance in a typical month of use?

      The appliance will use 123 kWh in a typical month.

   b. If you were paying 7.5 cents per kWh for electrical energy in your area, what would it have cost to use this appliance for a month?

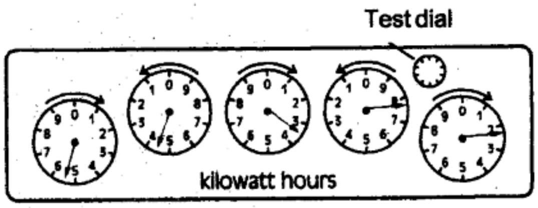
      Cost = kWh x Cost per kWh

      Cost = 123 kWh x 7.5 cents

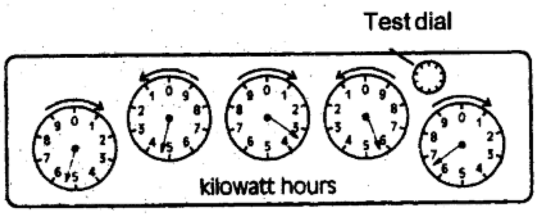
      Cost = $9.22

6. How many kilowatt hours has the consumer used between readings as shown in the two diagrams below? **16 kWh**

Reading Day 2



Reading Day 1



Notes

GRADE 9 SCIENCE (10F)

Module 4

Exploring the Universe

This module contains the following:

MODULE 4
EXPLORING THE UNIVERSE

Introduction

In Module 4: Exploring the Universe, you will begin your study with how ancient astronomers began to study the objects in the sky above them. Through the course, you will learn how to and why we measure objects, you will think critically about how the universe began, and you will examine modern space technology.

When you look at the sky after the sun has disappeared, it gradually becomes filled with spots of light. Some spots are bright, some dimmer, but they fill the sky with a beautiful array of lights that number about 2000 at any given time.

The bright spots are planets, stars, galaxies, and other celestial objects; some give off a steady light and some blink.

The last time you studied space science was Grade 6. At this time, you learned about the solar system and Earth's place in it. You also learned about space research, Canada's place in adding to knowledge about space, and the positive and negative impacts of this research. Topics covering the cycles of day and night, seasons, and moon phases were studied.

This year you will measure some objects in space and learn how these measurements were and are used on Earth. You will study the motions of some objects in space. You will attempt to answer questions such as "How did the universe begin?" and "What is a black hole?" Finally, you will take a look at modern technology that is pushing back space frontiers and answering some very interesting questions.

Your study in space science will begin with a history of how the ancient philosophers/scientists began understanding and using the objects in the sky above them.

You will notice that some of the lessons are accompanied by learning activities and assignments for you to complete. Complete the learning activities to help you learn about the information from the module, and check the answer keys in order to assess your understanding. Complete the assignments and submit them to the Distance Learning Unit according to the instructions found in the Introduction.

You will need the following materials to complete this module:

- thick corrugated cardboard (approximately 8½ x 11 inches)
- scissors
- 20 cm of thin string or coloured fishing line
- small weight (e.g., washer, nickel)
- large drinking straw (at least 0.5 cm in diameter)
- glue stick
- transparent tape
- orienteering-type compass
- simplified star chart or planisphere (available from various sites online)
- metre stick
- small protractor
- centimetre ruler

Learning Activities

There are several learning activities placed throughout this module, which will help you practise using the information you will learn. The answer keys for each of these learning activities are found in Module 4 Learning Activity Answer Key. Check the answer key carefully and make corrections to your work.

A **computer with Internet access** would be beneficial throughout the course. Additional support materials for the course are provided on websites that are listed. All of the URLs listed in this course were working when this course was written, but, since Internet sites come and go, you might find that some of these sites are no longer active or appropriate. If that happens, you could use a search engine (e.g., www.google.ca) to find the information that you are looking for.

Assignments in Module 4

When you complete Module 4, you will submit your Module 4 assignments, to the Distance Learning Unit either by mail or electronically through the learning management system (LMS). The staff will forward your work to your tutor/marker.

Lesson	Assignment Number	Assignment Title
2	Assignment 4.1	Measuring Altitude
3	Assignment 4.2	Locating Celestial Objects Using a System of Coordinates
4	Assignment 4.3	Path of the Sun and the Moon
8	Assignment 4.4	Monitoring the Retrograde Motion of the Planet Mars
8	Assignment 4.5	Life on Mars
9	Assignment 4.6	Measuring in Space
11	Assignment 4.7	Stars
14	Assignment 4.8	Mars Colony Project

Notes

LESSON 1: A BRIEF HISTORY OF ASTRONOMICAL SCIENCE

Lesson Focus

After completing this lesson, you will be able to

☐ name the philosophers/scientists and state their contributions to the study of space science

☐ describe how a scientific model can change as more information becomes available

☐ describe the terms *geocentric*, *retrograde*, and *epicycle*.

☐ describe how the Greek philosophers overcame the problems that other cultures experienced with mythology

Key Words

- astronomy
- *Almagest*
- geocentric
- retrograde
- epicycles
- astrolabe

Online Resources

The following websites provide information about space science.

- Encyclopædia Britannica
  www.britannica.com/EBchecked/topic/458717/physical-science
  This Encyclopædia Britannica resource has a free 14-day subscription, which allows you to use the full encyclopedia.
- Wolfgang R. Dick
  www.astro.uni-bonn.de/~pbrosche/hist_astr/ha_pers.html
- University of Tennessee
  http://csep10.phys.utk.edu/astr161/lect/index.html

The Beginning of Astronomy

About 4000 years ago, Egyptians would look at the Sun as it moved across the sky and speculate that a sacred boat was taking the Sun god Ra from the eastern shore, travelling across the heavenly ocean, setting at its western shore, and continuing, through the night, to travel through the underworld until it once again began its journey from the East.

As time passed, hunters and farmers observed that the heavenly objects viewed at night followed a pattern of movement. These hunters and farmers—we can call them the first primitive astronomers—used the repetition of the patterns in the sky to predict seasons. Accurate determination of seasons was important to their survival. As a result, they began keeping accurate records and developed charts of sky patterns. This is how the science of astronomy began.

Ancient civilizations, as demonstrated by Egyptian mythology, observed but did not understand the movements of stars and planets. The Egyptians, Babylonians, and others had developed mathematical tools, made observations, and kept records of their observations, but they did not use these tools to develop any models concerning the cause of star and planet movement. Greek civilization was the first to break away from mythology and superstition for several reasons:

- Greek civilization encouraged questioning minds. It was natural for a Greek to ask "why?" It is your job as a science student, like all scientists, to also ask "why?"

- The political structure in Greece had no strong central government to dictate social structure or thought. As a result, the Greeks were conditioned to question the mythology that surrounded their culture. The stage was set for an advance from accepting gods that controlled their environment to one where natural causes determined the motion of the heavens.

Thales

One of the earliest Greek astronomers was Thales. He was born around 624 BCE. The information we have about Thales is sketchy, but he is thought to have been a merchant and businessman. Because of his occupation, Thales probably travelled widely and spent time in Egypt. Thales is considered to have been the first of the Greek philosophers to move away from supernatural explanations of the natural world. Thales said the earth floats on water and that all the different parts of the earth, from mountains to trees, were also made of different states or forms of water. We know that his theory was not correct, but it does point out that Thales had developed a theory that didn't depend on mythology.

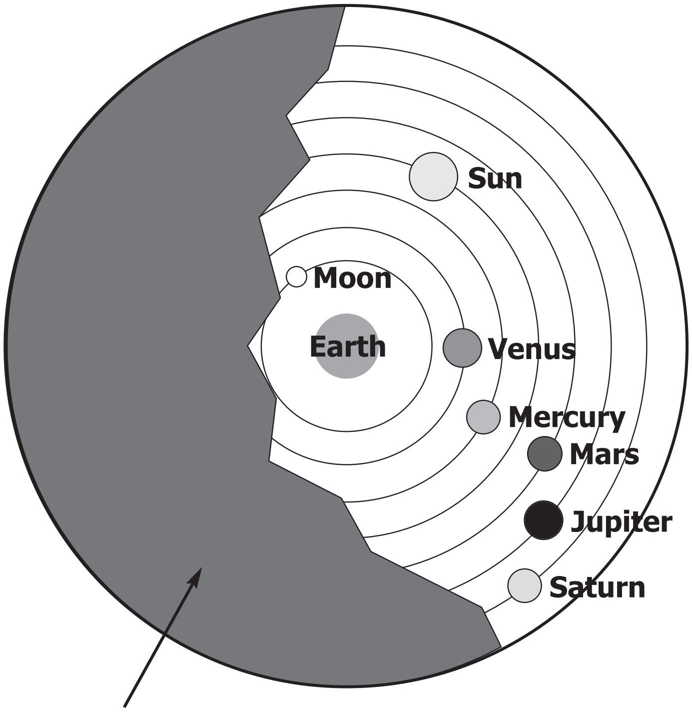
Aristotle

Aristotle was born on 384 BCE. He was a star pupil in Plato's Academy in Athens and became the first person to develop a system to explain how the universe worked. Aristotle affected science for centuries, and he showed that grand theories, explaining the workings of the universe, were possible.

Aristotle's stature as a philosopher was so great that his theories about all aspects of science—not only astronomy—were generally thought to be absolutely correct for almost two thousand years. Aristotle developed several concepts with regard to the universe and Earth's position in it.

- Spheres that rotated around Earth carried stars, planets, and the Sun. Earth was a spherical ball in the centre of the spheres and was therefore the centre of the universe.
- Stars were located on the inside of the largest sphere that rotated once a day around the earth.
- Planets were located on smaller, transparent spheres that rotated at different speeds and on different axes. This could explain why planets seem to move inside the "sphere of stars." The transparent spheres explain why we can see planets and stars.
- The universe is perfect. The circle is a perfect geometric shape. The planets and Sun and all heavenly objects must move in circular paths around Earth.

These first four concepts formed what Aristotle called the celestial sphere. You can see from the diagram below that the stars were fixed on the inside of the outer sphere. Earth is in the centre of the sphere; the planets and Sun are arranged around Earth. The planets, Sun, and all objects in space revolved around Earth in specific orbits at their own speeds.



Aristotle's firmament of fixed stars or celestial sphere is the farthest sphere from Earth. The stars are located on the inside of this outer sphere.

We still use the celestial sphere today for navigation purposes.

Aristarchus

Aristarchus was born on 310 BCE, and he became a brilliant mathematician who spent a great deal of time studying the universe. Aristarchus is mentioned in this brief history for two reasons. First, he was able, through painstaking observation, to develop a remarkably accurate picture of some aspects of the universe 2000 years ahead of his time. He was able to declare that the Sun was a huge ball of fire and that the Sun, planets, and stars did not revolve around Earth, but that Earth and other planets revolved around the Sun.

Secondly, Aristarchus is mentioned because he represents a common dilemma at that time—whose theory do you believe? Aristarchus's theory was not accepted because it didn't seem to fit observations. It seemed reasonable that if Earth was moving through space, people should feel the movement.

Hipparchus

Many consider Hipparchus the greatest of the Greek astronomers. He was able to

- using just his eyes, compile an extensive star chart of 850 stars, which included a classification of stars according to their brightness—his star chart was used for centuries
- calculate the distance to the moon
- discover that the axis of rotation of Earth changes over time (called precession)
- develop a system of epicycles to help explain the movement of planets in a geocentric system

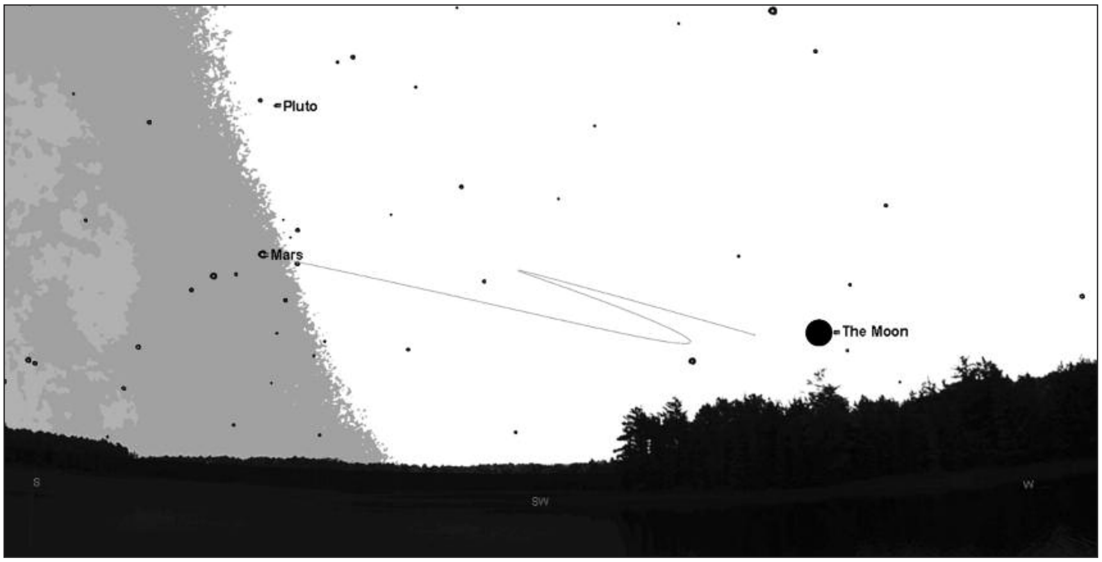
Ptolemy

Ptolemy was born Claudius Ptolemaeus (his name in the Latin language of the Roman Empire) in 100 CE. His name was changed to Ptolemy (it is pronounced as "toll–e–me") and it is by that name he is known today. Ptolemy is generally regarded as the best astronomer in ancient times.

Ptolemy presented his picture of the universe as we know it in a book called the ***Almages***t in which he summarized Greek knowledge up to that time. Ptolemy spent many years studying Aristotle and Aristarchus. He chose to side with Aristotle and describe a universe that was Earth centred. This is a good time to stop and consider two developments:

- The term *Earth-centred* is one that you learned in Grade 6 Science. We will use a more scientific term and call it **geocentric**.
- Those who had observed objects in the sky noticed there were some that seemed to "wander" from month to month, and seemed different in their motions when compared to all other stars. These objects would travel in a west to east direction across the sky over time, sometimes change direction to travel east to west for a period, and then go back to the original west to east direction. The apparent direction of motion for these objects was always measured against the background of the stars. The Greek name for wander is "planetos" and that is the name by which we know them to this day. When a planet wanders backwards in terms of its initial motion, we call the motion **retrograde**.

Below is a sky map that shows the retrograde motion of the planet Mars over a period of weeks. The "back and forth" line on the map shows the position of Mars over many months—see the "retrograde loop"? You could plot a similar path on a sky map if you were to view Mars every few nights and plot its position carefully. About every two years, you will have a good opportunity to view Mars in the night sky. The years 2009, 2011, 2013, and 2015 will work very well.



Graphic courtesy of Starry Night®/Starry Night Backyard, Version 4/Imaginova® Corp.

Ptolemy, with many philosophers of the time, had difficulty with retrograde motion because it didn't tie in with Aristotle's perfect universe. Ptolemy established a complex theory of **epicycles**—or little circles—to explain the retrograde motion of planets as seen from Earth. Ptolemy's explanations for all the different motions for all the different planets created a very complex theory that was difficult to understand and use.

Early Greek measurements were carefully and accurately done. The measurements were so good that discrepancies found many years later were due to changes in the motion of objects in space and not to any errors in measurement. As mentioned, one of the early Greek astronomers, Hipparchus, was able to mathematically calculate the size of the moon and its distance from Earth. Hipparchus's observations led him to explain the motion of planets as being outside of the centre of Earth. Ptolomy would lean on Hipparchus's observations and mathematical models for his explanations for the motion of planets.

Ptolemy represented the decline of the great philosophers. Exploration of the mysteries of the universe diminished for nearly 14 centuries as the culture that spawned such great thinkers came to an end. The Roman era began with Augustus Caesar in 27 BCE. The Romans, however, were not as interested in exploring nature for its own sake, but were more concerned with finance, engineering, and government. After the fall of Rome in the fifth century, a long decline of western civilization began. During this time the great library at Alexandria was destroyed and most of the works there were burned.

All was not lost, however, as the works of Aristotle and Ptolemy's *Almagest* reached Baghdad in what is now Iraq, one of the great cities of the Arab world. It was here, in fact, that Ptolemy's work was so highly regarded that it was named *Almagest* or the "great work." Ptolemy's Book 5 of the *Almagest* contains an account for constructing an astrolabe.

The Arab people were excellent observers. They soon refined an instrument that allowed them to fix the position of stars with high accuracy. The instrument is called an **astrolabe**. Arab astronomers were able to gather extremely accurate observations of star positions. In addition, Arab observations of planet motion and eclipses were responsible for the beginning of a revolution in astronomy in the Middle Ages. The Spanish king Alphonso X was able to persuade Arab astronomers to gather their observations and record them in what has come to be known as the Alphonsine tables.

Learning Activity 4.1: Astronomy in Ancient Times

1. Read your notes and any reference material you have that describes the meaning of **geocentric**, **retrograde**, and **epicycle**. Once you have read your reference material, write in your own words the meaning of the terms.

   a.

   b.

   c.

2. a. How did Aristotle and Aristarchus differ in their theories about the structure of the universe?

   b. Why was it difficult for the scholars of ancient Greece to decide whether they should believe and accept Aristotle's or Aristarchus's theory about the structure of the universe?

Check the answer key.

Summary

Astronomy's roots in ancient times are demonstrated by the early work of ancient Greek philosophers such as Thales, Aristotle, Aristarchus, Hipparchus, and Ptolemy.

LESSON 2: THE ASTROLABE

Lesson Focus

After completing this lesson, you will be able to

- ☐ use an astrolabe to determine the vertical position of an object in degrees
- ☐ determine the coordinates for the moon using an astrolabe

Key Words

- altitude
- azimuth

Introduction to the Astrolabe

You will construct and use an astrolabe in this lesson. Before doing the activity, there is some background information that will be helpful in understanding how an astrolabe works and its history.

Remember from the previous lesson that Ptolemy was the last of the Greek philosophers to make a contribution to the study of astronomy. Ptolemy's work, and the work of other Greek philosophers, was in danger of being lost when the greatest library in ancient times at Alexandria in Egypt was destroyed by a terrible fire at the hands of angry mobs (you may want to look up a story online about this event). In the early 800s an Arab ruler named Caliph Harun-al-Rashid set up a collection of the ancient works in what later became a research centre called the House of Wisdom in Baghdad. Scholars, bringing with them the ancient Greek texts, gathered there and continued their work. The Arab world was responsible for preserving these priceless writings.

The scholars brought with them instruments that had been developed over the centuries for various kinds of measurements in space. One of these instruments is called the **astrolabe**.

The astrolabe is an ancient tool that was used to solve problems relating to time and the position of the Sun and stars in the sky. Actually, there were a number of related mechanical instruments that could be called "astrolabes." The name comes from an old Greek word *astrolabos*, which in English means "to take a hold of a star."

These instruments were used to determine the positions of objects in the sky, and could be used as a kind of computer to calculate rising and setting times for objects like the Moon, Sun, and certain important stars. In this lesson, we will construct a simple astrolabe that can be used to measure the **altitude** (distance, in degrees, above the observer's horizon). We can also use it as a simple compass to determine **azimuth** (direction, in degrees, on the 360 degree circle that is all around us).

The history of the astrolabe begins more than 2000 years ago. The mathematical principles for the astrolabe were known before the calendar moved from BCE to CE, and the first recorded reference to what might be a primitive astrolabe were made by Ptolemy sometime between 100 CE and 200 CE. By the time the House of Wisdom was established in 800 CE, the astrolabe was a well-known and sophisticated piece of equipment.

You will use the astrolabe to determine the positions of different objects, but first you will need to construct the instrument. You will make a simple astrolabe as described below.

Learning Activity 4.2: Astrolabe Construction

Materials:

- thick corrugated cardboard (about 8½ x 11 inches or similar)
- scissors
- 20 centimetres of thin string or coloured fishing line
- weight (washer, nut, lead sinker, or similar object that can be tied onto the string)
- large drinking straw (at least 0.5 centimetre in diameter)
- glue stick
- transparent tape

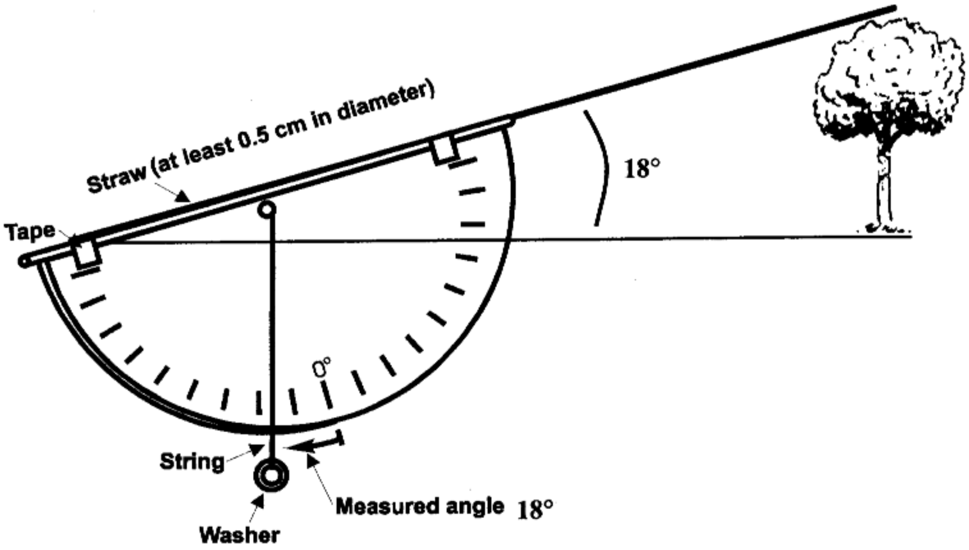
continued

Learning Activity 4.2 (continued)

Directions:

1. Carefully cut out the astrolabe template on page 23, according to desired size.
2. Glue the template securely to the cardboard, and then cut out the template cardboard in the semicircular shape of the template. Discard the remainder appropriately.
3. Carefully pierce a hole at the small circle in the centre of the template. You may wish to ask for assistance in this.
4. Put the string through the hole and tie a knot, and then tape it in place on the reverse side of the template. The string should now hang freely on the front side of the template.
5. Tie the weight to the end of the string so that it hangs at least 10 centimetres, below the edge of the astrolabe.
6. Tape the straw securely along the flat side of the astrolabe, and test to ensure that you can see through the straw.

The astrolabe that you have constructed should appear similar to the one pictured below. You should easily be able to sight large objects through the straw. Your device is now ready to be field tested with an activity involving the **altitude** of objects above the horizon. If you wish, you could also estimate the **azimuth**, which is a measure of direction when compared to north. For instance, an object on the north horizon would have an azimuth of zero degrees (0°). One on the east horizon would have an azimuth of 90°, and south 180°, and so on.



The astrolabe that you have built should look like the one above. Make certain the straw is large enough for you to see through. A straw with a diameter of at least 0.5 centimetres is needed. Use the astrolabe that you have built to do the following activities.

Learning Activity 4.3: Using an Astrolabe

The diagram on the previous page shows how the astrolabe can be used to determine the height of an object by measuring the angle the object makes above the horizontal. In the example above, the astrolabe is measuring the tree height as 18° from the horizontal or flat line. Notice that the angle between the string and the 0° mark on the protractor is the measured angle (18°). You determine the angle by measuring the number of degrees between the astrolabe and the string.

Use the astrolabe to determine the angle between the horizontal and three objects such as a tree, your house, and your friend. Enter the data you are collecting in the first two columns of your data table.

Determine the angle between two parts of a single object. For example, measure the angle between the top and bottom of a roof. First you can measure the angle to the top of the roof. Then measure the angle to the bottom of the roof and subtract the smaller angle from the larger. In the example above, the angle to the top of the tree is 18°; the angle to the bottom of the leaves might be 8°. The angle of the tree that contains leaves is 10°. Enter the measurement you have made for the angle of the roof into your data table.

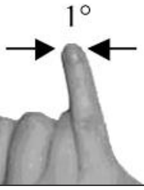
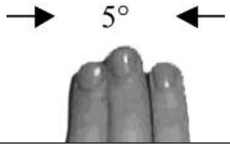
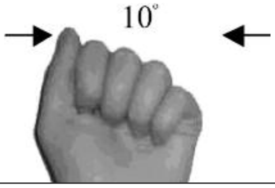
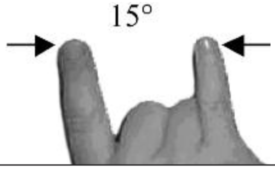
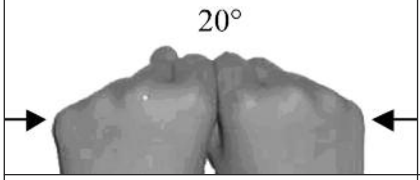
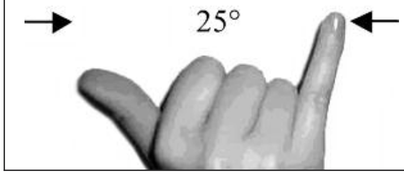
Object Viewed	Description of Object Being Viewed	Angle Using Astrolabe	Angle Using Hand

continued

Learning Activity 4.3 (continued)

Using Your Hand for Making Approximate Measurements

It is possible to use different parts of your outstretched hand to estimate angles. The following images of a hand will give you the estimated angles for each part of your hand when it is outstretched.

	When your hand is stretched out, your small finger will measure approximately 1° of space.
	Three fingers as shown at left will measure approximately 5° when your hand is outstretched.
	A fist as shown at left will measure approximately 10° when your hand is outstretched.
	The index finger to the small finger at left will measure approximately 15° when your hand is outstretched.
	Two fists will measure approximately 20° when your hand is outstretched.
	The thumb to the small finger will measure approximately 25° when your hand is outstretched.

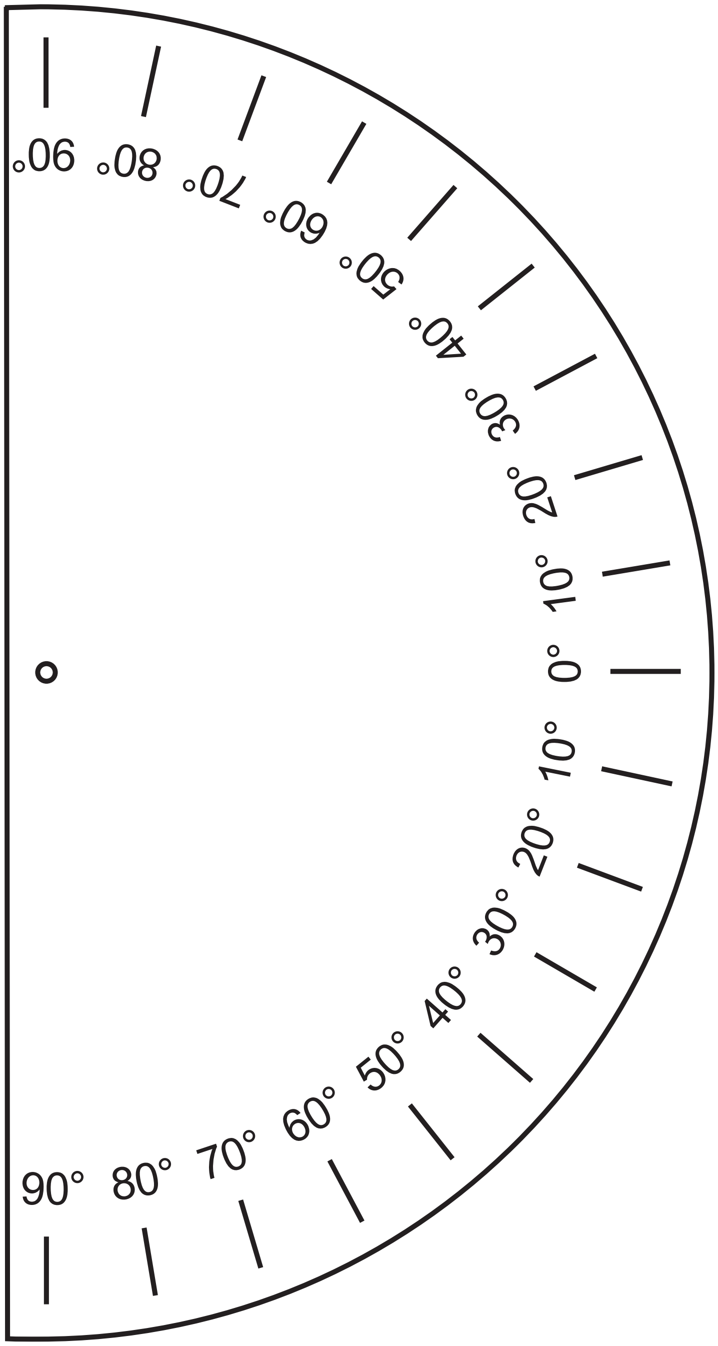
Use your hand to approximate the angle of each measurement you made with the astrolabe and complete the table with these measurements.

Summary

Astrolabes were being developed over 2000 years ago. They continued in use as an astronomical tool for measuring time and altitude. Arab astronomers were responsible for keeping some of the original writings of the Greek philosophers. Arab astronomers were also responsible for developing the new components to the astrolabe and passing it on the European community. Astrolabes were modified and used as a navigational tool on ships.

Notes

Astrolabe Template



Notes

Assignment 4.1: Measuring Altitude (8 marks)

Use the following questions to help you understand how measurements are made using an astrolabe and your hand.

1. Which of the two methods of measuring angles do you think is the most accurate? Explain. *(3 marks)*

2. a. How many fists would it take to measure from the horizon to a point straight up in the sky? *(1 mark)*

   b. If you used your astrolabe, what angle would question (a) measure? *(1 mark)*

continued

Assignment 4.1 (continued)

3. How many hand measurements, using the small finger to pointer finger method, would be required to measure from east to west going *(2 marks)*

   a. across the horizon?

   b. across the sky?

4. What happens to the angle shown on your astrolabe when you make two measurements of the same object? The first measurement is made when you are close to the object and the second measurement is made when you are farther away. *(1 mark)*

Lesson 3: Applying Coordinates to Celestial Objects

Lesson Focus

After completing this lesson, you will be able to

☐ explain the meaning of altitude and azimuth

☐ measure the altitudes of celestial objects

Key Words

- altitude
- zenith
- azimuth
- coordinates (altitude and azimuth)

The astrolabe can be used for astronomical measurements. The positions of stars, the Sun, and Moon can be accurately determined using the astrolabe you have constructed.

If you had measured a house with your astrolabe in the last lesson, you would know that if you went to the same spot every day for a week and measured the angle to the top of the house, it would remain exactly the same. You would say the reason is simple—the house didn't move! What happens when you use your astrolabe on objects that do *move* as Earth turns? Would you reply that the angle would change? If you did, you would be correct.

There is one other consideration you need to include when measuring the angle of a celestial object; that is, you need to consider the angle upward that you measure with the astrolabe and the angle to the left or right that you measure with a compass. To measure the position of an object in the sky, such as the Moon, accurately, you must have *two measurements*.

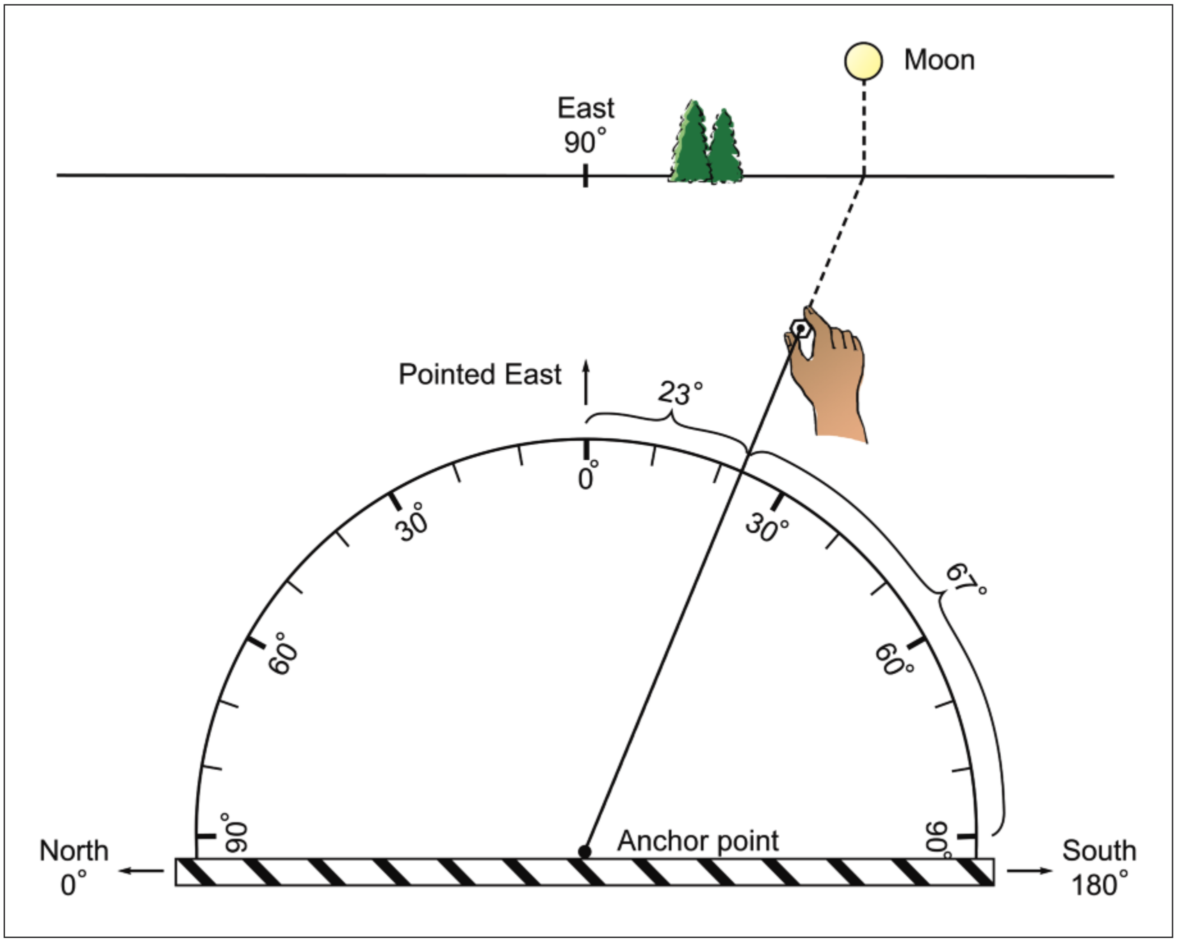
A vertical (upward) angle measured with an astrolabe is called the **altitude**.

The horizon would have an altitude of zero degrees. The **zenith**, which is a point directly overhead, will have an altitude of 90°. All objects in the sky have an altitude between 0° and 90°.

A horizontal (horizon) angle measured with a compass is called the **azimuth**.

The azimuth is the compass bearing of an object in space. An object that is due north has an azimuth of 0°. East has an azimuth value of 90°. South is 180°, and west is 270°.

When the position of a star or some other object in space is given using its altitude and azimuth, these are called its **coordinates**.



With the astrolabe held horizontally instead of vertically, and lining up your sighting straw north and south, **carefully** place your eye as close as you can to the anchor point of the string (see the diagram above). While sighting with the weight in your hand, align the string with the direction of your object—again, take a look at the diagram. Count up the number of degrees that the string is away from a value that you know. For instance, recall that north is 0°, east is 90°, south is 180°, and west is 270°.

To determine the azimuth of the Moon in our example here, it is ***due east* + *23*°= *113***°. You could also have said to yourself "the Moon is 180° MINUS 67°" which will also give you an azimuth of 113°.

Online Resource

The following website gives some detail about the concept of a celestial sphere where altitude and azimuth exist.

- University of Tennessee
  http://csep10.phys.utk.edu/astr161/lect/celestial/celestial.html

Learning Activity 4.4: Altitude and Azimuth

1. What are the coordinates of a star that is located southeast and is halfway from the horizon to the zenith?
2. What are the coordinates of the moon when it is due east and 20° above the horizon?
3. The North Star is called Polaris. Wherever you are located in the Northern Hemisphere, Polaris is always due north. The altitude of Polaris is always equal to the latitude on Earth’s surface from where you are observing the star, as long as you are north of the equator.

   What are the coordinates of Polaris if you are located at Norway House, Manitoba, where the latitude is 53.5°?
4. What are the coordinates for Polaris where you live?

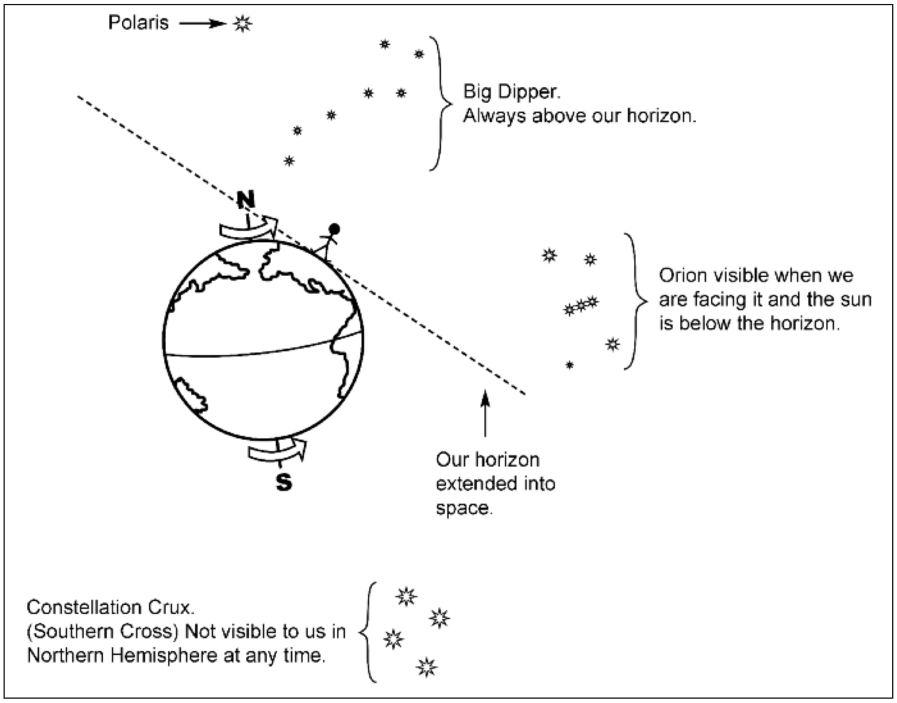
Check the answer key.

Further Information about Your Place in Space

In the diagram that appears below, imagine yourself standing on your world in Manitoba. We have greatly enlarged your body size to make you visible! Now, imagine a complete sphere of stars in the Milky Way galaxy surrounding Earth in all directions. ONE-HALF of these stars will be visible to you at any one moment.

As Earth turns (rotates on its axis), the stars will appear to move steadily as time passes. As seen in the diagram, some stars (like the North Star/Polaris) will ALWAYS be above your horizon—the dashed line—and we call these **circumpolar stars**. Others, such as the famous stars of the constellation Orion, will appear to rise and then set each day.

Still other stars, such as the Southern Cross or Crux as it is known, can never be seen from Manitoba, but are visible to those who are far enough south on Earth like people in New Zealand and Australia.



Summary

You need two pieces of information to track the position of objects in space: first, the altitude (the vertical angle in relation to the horizon); second, the azimuth (the horizontal angle in relation to the cardinal directions). Combined, these angles give you the coordinates of a celestial object. In the next lesson, you will put this knowledge to use by tracking the coordinates of Earth’s moon.

Assignment 4.2: Locating Celestial Objects Using a System of Coordinates (14 marks)

Purpose:

To use the constructed astrolabe and an orienteering compass to locate and determine the altitude and azimuth of a selection of objects in the night sky.

Note: If the activity cannot be done at night, substitute objects that are visible around you during the day, (e.g., buildings, trees). This is not, however, the most desirable option as we want to become more familiar with objects in the night sky.

CAUTION!

DO NOT directly observe the Sun as part of this activity.

Materials:

- student-constructed astrolabe
- orienteering compass for measuring azimuth (or use your astrolabe as we did earlier in this lesson)
- logbook or chart to record your measurements (see sample on page 32)
- star chart or *planisphere* (available from many sites online)

continued

Assignment 4.2 (continued)

Procedure:

1. Complete Observation Table 1 on the next page (or create a similar chart for recording): *(5 marks)*

    a. Select at least five objects in the night sky that you wish to locate and that will be visible at the time you are doing the activity. The following are the easiest to locate until you are more familiar with the night sky at your location: the Moon; bright planets such as Venus, Mars, Jupiter and Saturn; easy to find stars such as Polaris (the North Star), Vega, Sirius, and Arcturus. Also, try to pick objects in different parts of the sky.

    b. Using the compass, or astrolabe held horizontally, determine the **azimuth** of the object by visually tracing a line from the object in the sky straight down to the nearest horizon point, and reading its compass bearing (e.g., 0 degrees is due north, 90 degrees would be due east, 180 degrees would be due south and 270 degrees would be due west). Record this in your chart or logbook.

    c. Using the "hand-angle technique" that you have learned and practised, estimate the **altitude** of the object of interest. Record your estimates in the chart or a personal observation logbook.

    d. Using the astrolabe, look through the straw until you can see the object centred in the field of view. While holding the instrument steady, use your free hand to pinch the string against the scale on the astrolabe until you are able to record the altitude. Repeat this at least two more times for the same object, and average the three readings in order to increase the precision.

continued

Assignment 4.2 (continued)

Observation Table 1

Date and Time of Observation	Object Viewed	Azimuth	Altitude Estimate Using Hand-Angle Technique	Altitude as Measured by Astrolabe

continued

Assignment 4.2 (continued)

2. On the SAME NIGHT, go out two or three hours LATER and determine the ALTITUDE and AZIMUTH of the same five objects on the sky. When you redo these measurements, you will notice a change in both altitude and azimuth values. Complete Observation Table 2 on the next page (or create a similar chart for recording) to record your values, and take note of any changes that seem to occur. *(5 marks)*

3. Answer the following questions about your observations:
   a. How does the azimuth of your object change over time? *(1 mark)*

   b. How does the altitude of your object change over time? *(1 mark)*

   c. Do the bright stars near Polaris move very much over a few hours? Explain why you think this might be. *(2 marks)*

continued

Assignment 4.2 (continued)

Observation Table 2

Object/Date/Time	Altitude Early in Evening	Altitude Later in Evening	Azimuth Early in Evening	Azimuth Later in Evening

Notes

LESSON 4: COLLECTING DATA FROM CELESTIAL OBJECTS OVER A PERIOD OF TIME

Lesson Focus

After completing this lesson, you will be able to

☐ create a graph showing the angle a celestial object makes with the horizon over a period of time

☐ be able to draw information from your graph and comment about what motions are responsible for the data you are working with

You are going to put your astrolabe to work again. This activity will require you to perform measurements of the moon over a period of at least 12 days.

Learning Activity 4.5: Observing and Charting the Moon

Observe the altitude and azimuth of the moon over a period of 14 days starting at the new moon and continuing to the full moon.

Materials:

- astrolabe to measure altitude (made in Lesson 2)
- logbook to record measurements
- orienteering-style compass to measure azimuth (optional—you can use your astrolabe for this too)
- simplified star chart

continued

Learning Activity 4.5 (continued)

Procedure:

1. Use a calendar to find when the next new moon begins. Start your measurements two or three days after the new moon so that a beautiful, narrow crescent can be seen on the western sky just after sunset.
2. Use a compass to determine the azimuth of the moon. **Make your measurements at the same time every day.** A convenient time might be at dusk. If you are not certain how to use a compass, ask someone who knows. If you are not able to locate a compass, use the astrolabe method to determine the azimuth.
3. Use your astrolabe to measure the altitude each night at the same time you determine the azimuth.
4. Record your results each time you make a measurement.
5. Continue your measurements for at least 12 nights. Please note that weather and clouds may affect your ability to observe. **You can record your data in the chart provided on the following page (a sample data set is included to help you).**
6. Plot your data on the graphs provided for you. On the first graph, plot **azimuth vs day number. On the second graph plot altitude vs number of days**. See the rubric on page 43 for details about what to include in your graph.

Note:

When you are making your graphs, draw large dots to show each measurement. Join the points on your graph by drawing a line between each point.

continued

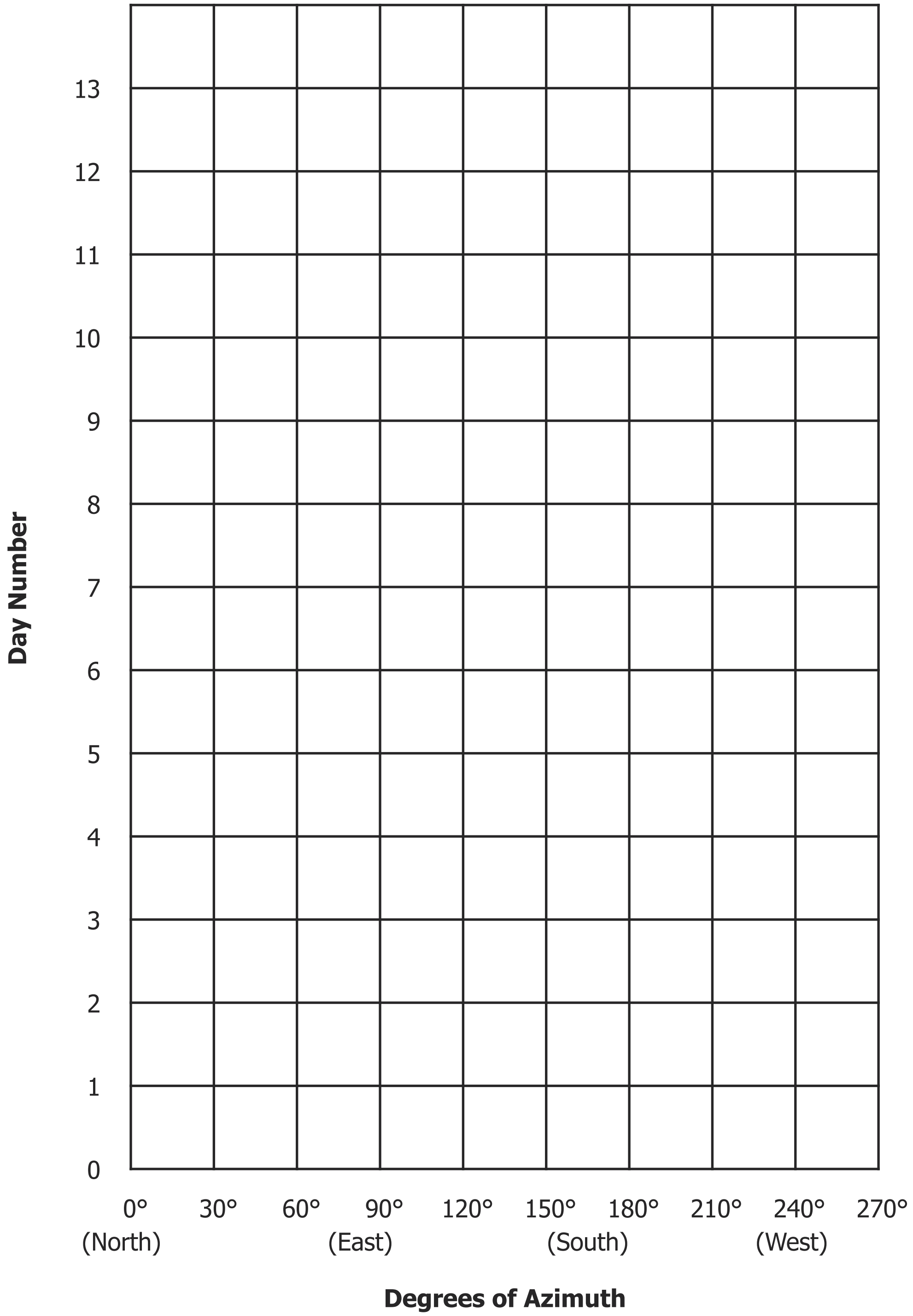
Learning Activity 4.5 (continued)

Date and Time of Observation	Altitude of Moon	Azimuth of Moon	Moon's Appearance	Percentage of Illumination of Moon
March 29, 2010 10:30 p.m.	12°	290°		~ 15 %
March 30, 2010 10:30 p.m.	CLOUDY SKIES			
March 31, 2010 10:30 p.m.	35°	270°		~ 30%

continued

Learning Activity 4.5 (continued)

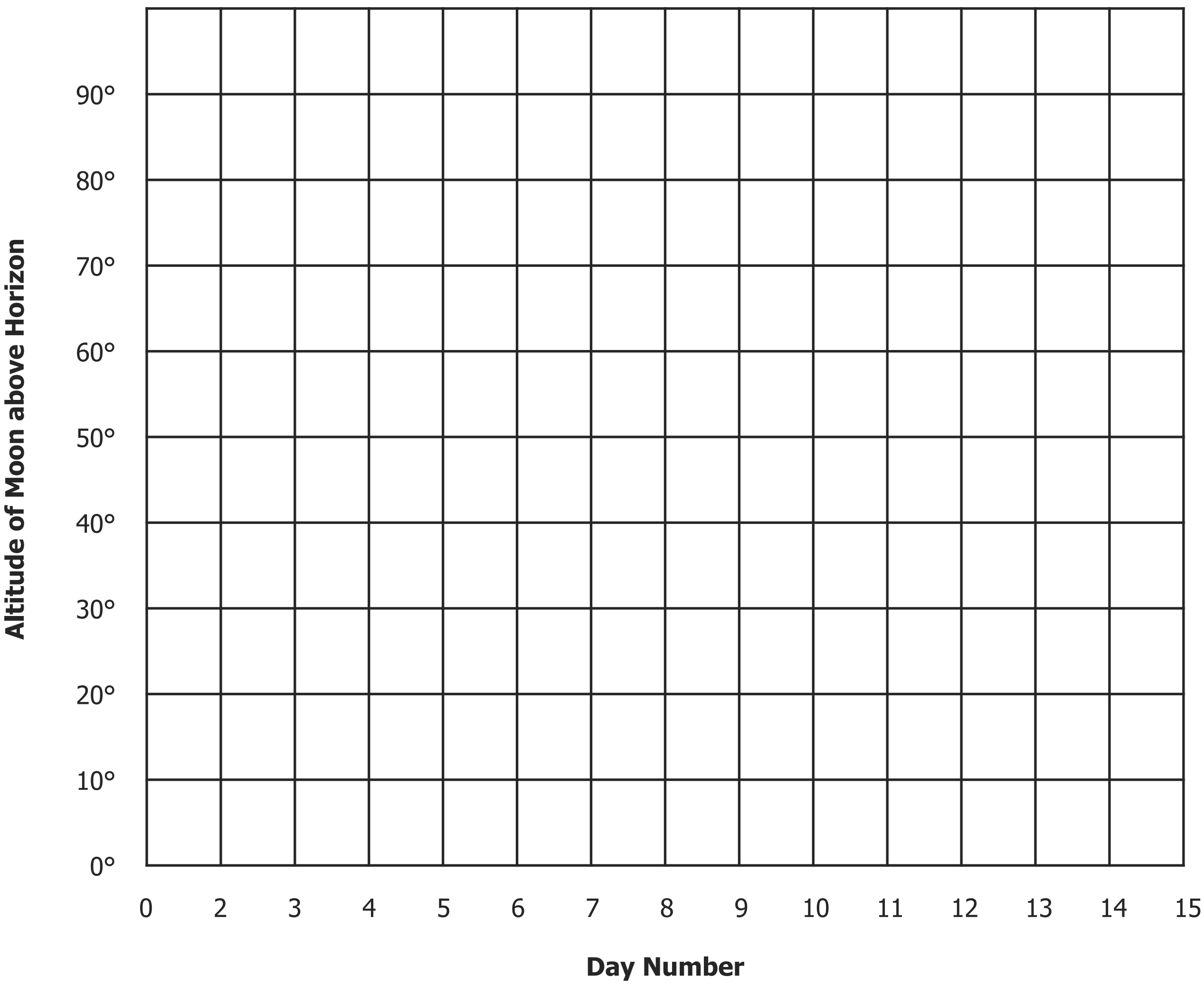
Azimuth of Moon versus Day Number



continued

Learning Activity 4.5 (continued)

Altitude of Moon versus Day



continued

Learning Activity 4.5 (continued)

You might be interested in plotting some more graphs showing the azimuth and altitude versus days, weeks, or months for some other space objects. You might like to use Polaris, the Moon, or one of the brighter planets such as Venus, Mars, or Jupiter.

CAUTION!

DO NOT use the sun for your measurements.

The risk of permanent eye damage is too great.

If you want to measure the azimuth and altitude of a star or a planet, you will need a star chart. Star charts can be located from a number of sources such as books and magazines, but one of the easiest sources is the Internet. Use these charts to locate different objects in space.

Online star charts for each month of the current year can be accessed online at the site below:

Online Resource

The following website has links to practical astronomy.

- About.com
  http://space.about.com/od/computerresources/Computer_Resources_for_Astronomy_and_Space_Exploration.htm

If you want to observe the change in position of the Sun, stars, or planets, you will need to make measurements over longer periods of time. It would be best to use months instead of days for your horizontal axis. If you measured 12 columns in your graph, there will be enough room on your graph for one year's measurement. Remember, you will make one measurement each month if you want a graph of the Sun's coordinates at sunset for a year.

Check the answer key.

This graphing rubric will be referenced during Assignments 4.3 and 4.4.

Graphing Rubric

Checklist of Graphing Skills Name: ____________________

	NI	S	E	Comments
Standard Elements — selects appropriate type of graph				
— uses appropriate scale for each axis				
— chooses appropriate origin and intervals along each axis				
— labels axes clearly				
— states in the graph's main title the relationship between axes				
— places independent variable on the *x*-axis				
— places dependent variable on the *y*-axis				
— includes key or legend when necessary				
Data — plots data accurately				
— depicts trends (when applicable)				
Presentation				
— uses space on the graph appropriately				
— uses space on the paper appropriately				
— graphs neatly and clearly				
— depicts trends clearly, so they are easy to interpret				
Interpretation				
— identifies and explains errors in data-collection methods				
— determines and explains trends or discrepancies in trends				
— demonstrates understanding of associated scientific concepts				

Summary

Now that you have practised measuring celestial objects, you will put your skills to the test with the next assignment. In this assignment, you will observe data on the motions of the Sun and Moon, taken over the course of a year.

Assignment 4.3: Path of the Sun and the Moon (23 marks)

The data below is collected over a period of one year for the Sun's azimuth at sunset. These data were collected at Teulon, Manitoba, by students over almost one year.

Day	Azimuth of Sun at Sunset
21	240°
51	255°
80	272°
110	290°
140	305°
170	310°
200	305°
230	290°
260	272°
290	255°
320	240°
350	230°

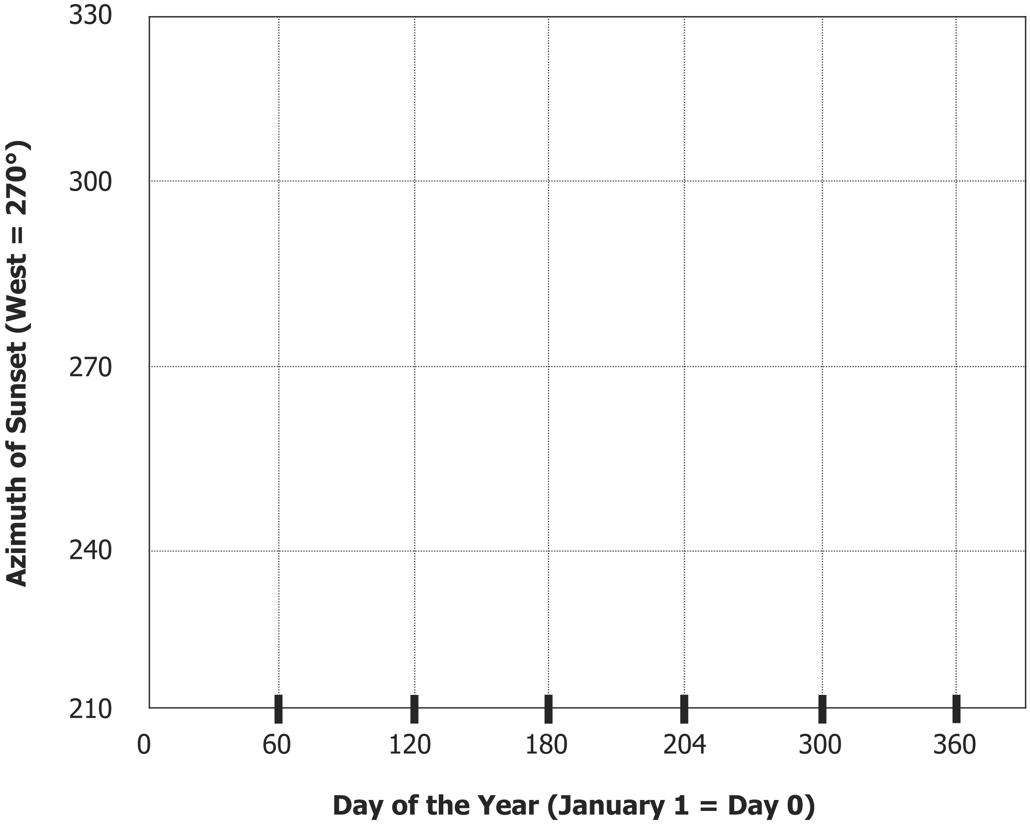
1. Plot the azimuth of the setting Sun over the period of one year on the graph on the next page using these data. *(8 marks—see graphing rubric on page 43)*

continued

Assignment 4.3 (continued)

Question #1 (continued)

Plot of Sunset Azimuth at Teulon, Manitoba



2. How would you describe the position of the sunset over the course of a year from January to December? *(2 marks)*

continued

Assignment 4.3 (continued)

3. At what time(s) of the year does the Sun set exactly in the west (at azimuth 270°)? *(2 marks)*

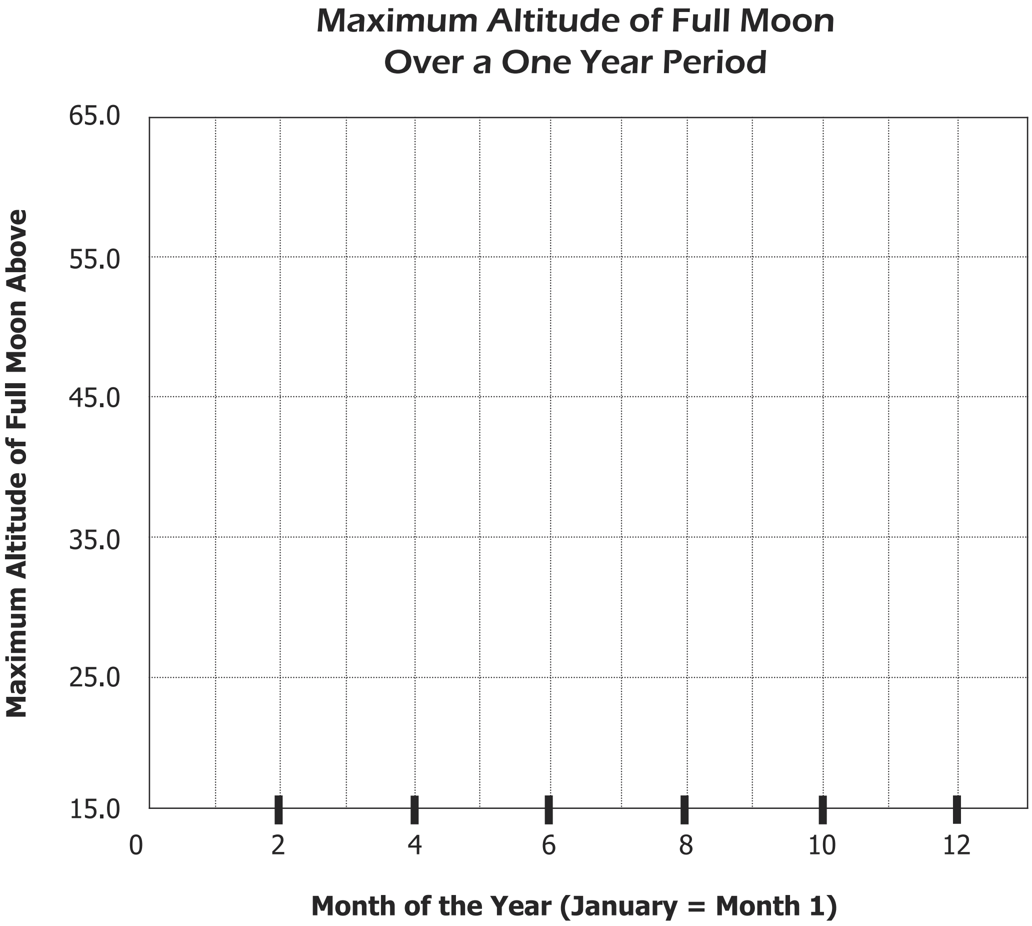
   The data below were collected over one year at the time of each full moon:

Month	Full Moon's Maximum Altitude (Degrees above horizon)
January	60°
February	55°
March	48°
April	35°
May	24°
June	20°
July	18°
August	21°
September	30°
October	42°
November	50°
December	60°

continued

Assignment 4.3 (continued)

4. Plot the moon's maximum altitude over the period of one year on the graph below using the data from Question 3. *(8 marks—see graphing rubric on page 43)*



continued

Assignment 4.3 (continued)

5. How would you describe the position of the Moon (at its maximum altitude) over the course of a year from January to December? *(2 marks)*

6. For ancient peoples in the Northern Hemisphere, how might the Moon's seasonal changes in altitude have benefited them? For instance, the Manitoba Cree Nation calls the Moon **"tipiskow pissim"** which means "the night sun." *(1 mark)*

Notes

LESSON 5: COPERNICUS, KEPLER, GALILEO, AND NEWTON— THE HELIOCENTRIC COSMOS

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe the contributions of Copernicus, Kepler, Galileo, and Newton to the development of a heliocentric model of the solar system
- ☐ describe how Kepler, Galileo, and Newton demonstrated the increasing role of mathematics and a natural science approach to understanding the mechanics of the universe
- ☐ describe how the telescope contributed to a more complete understanding of the motions of—and what makes up—planets, moons, and stars

Key Words

- heliocentric
- telescope
- elliptical
- Law of Universal Gravitation

Online Resource

The following website provides an extensive history of people involved in astronomical sciences.

- Wolfgang R. Dick
  www.astro.uni-bonn.de/~pbrosche/hist_astr/ha_pers.html

Introduction

Ptolemy was completing his theory regarding the motion of the planets around 150 CE. You might remember that he agreed with the geocentric theory of the solar system. Ptolemy spent a great deal of time developing an explanation for the geocentric theory that eventually resulted in an extremely complex system of spheres of motion with smaller spheres of motion inside. This would help explain the retrograde motion in planets that was observed by the natural philosophers of centuries ago.

The model that was developed by Aristotle and generally accepted by most who were interested contained some key principles:

- The planets and stars travelled on crystalline spheres that were transparent. The stars formed a backdrop, called the celestial sphere, to the planets and Sun that each travelled in their own spherical orbits around Earth, forming an Earth-centred (geocentric) system.
- The space between the planets, Sun, and stars was filled with a substance called ether, as it was thought impossible to have a vacuum in space where there was no stuff.

There was a set of laws governing motion on Earth's surface and a separate set of different laws governing the motion of planets, Sun, and stars.

The burst of intellectual activity that characterized Greek society diminished until Ptolemy's time when it almost disappeared entirely, and some great libraries were destroyed by those who thought anything other than religious knowledge was a real danger. The destruction of libraries meant the loss of accumulated knowledge based on observations over centuries. This was a great loss for astronomy—perhaps the oldest of the sciences and one that relied upon data that was very carefully logged.

The Arab cultures of the Middle East had leaders who welcomed intellectual people from many countries and languages. As a result, the Arab world became a kind of "keeper of wisdom and knowledge."

Ptolemy's work was highly respected in the Arab world. Ptolemy's writing was gathered into a single document called the *Almagest*, which meant "the great work" in Arabic. Ptolemy's incorrect model was studied and accepted as being correct for many centuries.

Approximately 1400 years later, the knowledge gathered in the Arab countries began to filter into Spain and Europe. The stage was now set for the next leap in understanding the heavens.

It seems to us now, in hindsight, that the geocentric model is obviously incorrect. We need to keep in mind, however, that several factors were in play during this time.

- Astronomy, in early times, had no "scientific method" as we understand it now; however, the early astronomers were very patient and keen observers with remarkable success in explaining the movement of objects in the cosmos.
- A theory would be greatly affected by the reputation of its proponent. Aristotle's reputation was so widespread that his ideas could not easily be challenged or set aside.
- Later, after the church of the day began to influence thought in the educational and scholarly communities, any theory of the cosmos that appeared to be contrary to the church's official position on matters of faith would be seen as suspicious and be vigorously opposed. You can read about the difficulties that Copernicus and Galileo experienced in their work.
- There were no telescopes for these individuals to use. This, the most significant tool available to astronomers, was still missing.

Nicholaus Copernicus

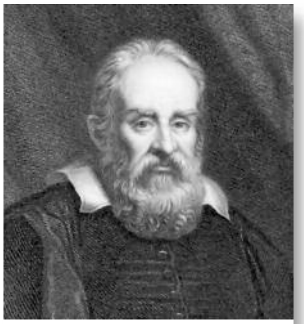
Copernicus was born in 1473 in Poland with the name Nikolai Kopernic. We know him by the Latin version of his last name. He studied in the University of Krakow and also in Italy. Copernicus studied to become a priest in the Polish Catholic Church; however, he was given a post that involved some clerical duty and a good wage, but no obligations as a priest. As a result, Copernicus had ample opportunity to pursue his interests in astronomy. He had read Ptolemy's works and could not agree that a description of the motion of planets needed to be so complicated.

Copernicus decided that he would try to develop a model for the motion of planets that would be simpler. He remembered there were a few Greek astronomers such as Aristarchus who disagreed with Ptolemy and stated that a Sun-centred solar system was a better description. When Copernicus placed the Sun in the centre and had the earth travel around the sun, many of the complexities of Ptolemy's model disappeared. The modern Sun-centred view of the solar system was born, but not into a world that accepted the idea very quickly. The Sun-centred system is called the heliocentric system.

Copernicus hesitated to publish a book called *Concerning the Revolution of the Heavenly Spheres* as he wanted to verify some mathematics in his theory and as he was very concerned about presenting a theory that was in open conflict with the Church at the time. Finally, persuaded to publish his book, he became ill and died within hours of its publication—or so the history tells us.

Galileo Galilei

Galileo was born 1564 near Pisa, Italy. Galileo was the founder of the modern scientific method. In an age still subjected to mysticism and the occult, he demonstrated that there were rational explanations of the natural world.



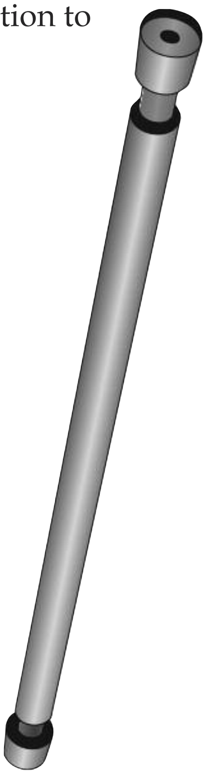
Galileo

Galileo is a giant in space science and science generally because he is the first to state and use the scientific method effectively. He would show, at every opportunity he could, that observation and measurement overcame many of the wrong ideas held as being true for so many centuries. For example, Galileo would weigh an empty ball, pump air into it and reweigh the same ball. The scales would clearly show an increase in weight due to the air. This result contradicted Aristotle's carefully constructed proposition that air had no weight because it was colourless.

Galileo's reputation for careful investigation of the facts made him extremely influential when he turned his attention to astronomy. His serious interest in astronomy began when Galileo heard of a new instrument called the **telescope** built in Holland by Hans Lippershey. Galileo immediately recognized the instrument's potential for studying the heavens and by 1609 he had built one of his own. This was the starting point for a detailed study of objects in space for Galileo. It also meant that scientists now had a tool that would allow them to observe heavenly objects.

Judged by today's standards, Galileo's telescope was a primitive affair, but it opened up the universe to him. First, he studied the moon. Galileo saw the moon wasn't a perfect sphere, as all objects in space were thought to be. Instead, the moon was riddled with craters, valleys, and mountains.

Next, Galileo began looking at stars. He discovered that what looked a mist was really millions of stars forming the band of light called the Milky Way. His telescope then pointed to the bright planets that were visible to the eye. There, Galileo saw Jupiter with three, and then, a few weeks later, four distinct moons. The moons travelled around Jupiter and not Earth, as they should have in the geocentric model.



Galileo's Telescope

Venus showed distinct phases, much the same as the Moon does over a period of one month. The only explanation for these phases was the Sun shining on Venus and the light being reflected back to Earth as Venus travelled around the Sun and not around Earth.

Galileo could not stop describing the Ptolemaic or geocentric system as now having some real problems, and it seemed that the Copernican or heliocentric system was showing real promise in predicting some of his observations. Galileo was so convinced in his conviction that the Copernican system was correct that in 1632 he published a book in Italian called *A Dialogue Concerning the Two Chief World Systems – Ptolemaic and Copernican.* The awkward and long title of the book described the nature of what was to be found there for the reader; in the story, Galileo sets it up as a dialogue between three characters—Salviati, who represents the adventurous-thinking man of science and is thought to be Galileo himself; Sagredo, who is the one who represents an open-minded public figure willing to listen to new ideas; and Simplicio, who is dressed as a man of the Church, and who stubbornly holds on to Aristotle's ideas. This was bound to cause Galileo some difficulties with the leadership of the Italian church.

Title page of Galileo Galilei's 1632 book *A Dialogue Concerning the Two Chief World Systems—Ptolemaic and Copernican*.*

When the book was published, Galileo was called into the Vatican where he was accused of holding onto and teaching ideas that were opposing those traditionally believed (that is, making statements contrary to Church doctrine). He was never brought under threat of torture, as some seem to believe, nor was there a grand trial in front of hundreds of Church leaders. Galileo's trial was a small-scale meeting with just a few individuals.

As Galileo had by this time become rather old and his eyesight was diminishing, the Church only asked him to deny his findings, stop teaching about Copernicus's ideas, and publicly state Ptolemy was correct. The Church did this for several reasons. Galileo's defense of his propositions was logical and based on scientific measurement. Galileo was respected throughout the country of Italy at the time for his great contributions to the scientific understanding. Today, he would likely be a television personality on a science program.

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*Source: Douma, Michael, curator. ``Galileo Galilei: *Dialogue Concerning the Two Chief World Systems." Calendars through the Ages.* 2008. Institute for Dynamic Educational Development. www.webexhibits.org/calendars/year-text-Galileo.html (16 June 2010). Reproduced with permission.

The heliocentric model was gaining acceptance for several reasons:

- Galileo's observations of the Moon revealed it to be less than perfect. This was contrary to Aristotle's statement that objects in space were perfect.
- Galileo's discovery of moons travelling around Jupiter was proof that not all objects travelled around Earth.
- The phases of Venus, much like the phases of the Moon, indicated Venus travelled around the Sun.

Online Resource

The following website provides background information about Galileo.

- University of Tennessee
  http://csep10.phys.utk.edu/astr161/lect/history/galileo.html

Johannes Kepler and Tycho Brahe

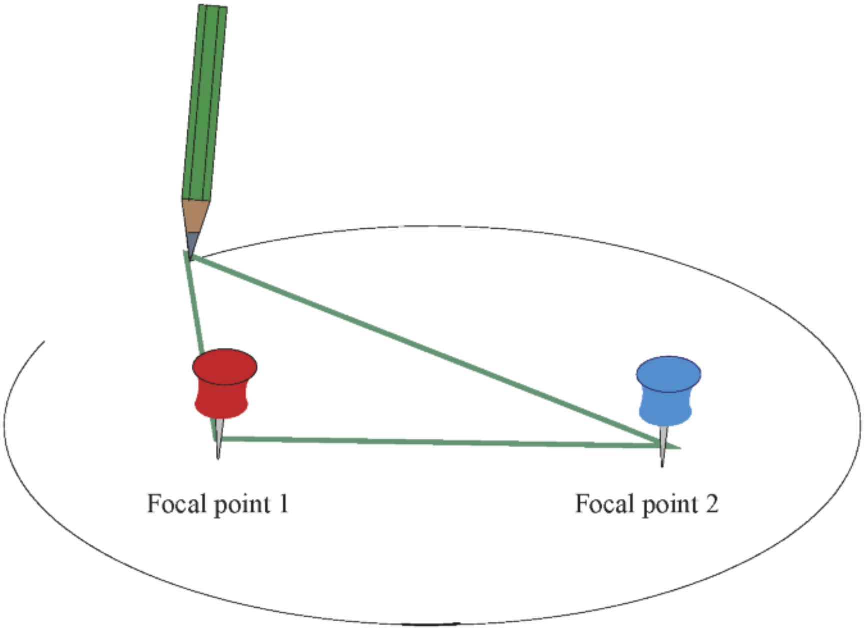
Kepler was born in 1571. In 1600, he started working as an assistant to the Danish astronomer, Tycho Brahe.

Tycho Brahe was a colourful, brilliant man who loved great feasts. Written accounts say it is true that he had a nose made of metal. This strange apparatus became necessary when part of his nose was sliced off in a duel with a mathematician over some point of mathematics! He had built one of the best observatories in the world and filled it with the best instruments for measuring heavenly objects. He carefully measured the positions of 777 stars and five planets that were known at that time.

Tycho's passion was to prove Copernicus incorrect. He had observed a comet pass through what would have been the crystalline spheres proposed by Ptolemy, so he had to admit that Ptolemy's model was not correct. Tycho, however, was a strong supporter of the geocentric model, so he developed his own geocentric model. This model argued that, while the planets revolved around the Sun, the Sun and Moon revolved around Earth.

We might scoff at this attempt to explain the motions in our solar system, but Tycho, in the process of making his measurements, gathered an incredible set of data about the positions of stars and planets. His calculations, based on his measurements of objects in space, actually explained their motion. Tycho died in 1601 hoping that his assistant would verify his model.

Kepler, however, never accepted his mentor's theory. He felt that Copernicus was correct. Kepler decided to analyze the motion of Mars from Tycho's data. If he knew the motion of Mars, he reasoned, the motion of the other planets could be easily determined. After years of painstaking effort, Kepler, who once stated the job would take only eight days, was able to confidently state that Mars travelled around the Sun in an **elliptical** orbit. An ellipse is an oblong shape that has two focal points. A circle is a special ellipse that has only one focal point that we call the center of the circle.



You can easily make an ellipse using two tacks, a pencil, and a piece of string as shown in the diagram. Make certain the string loop is longer than the distance between the two tacks. Place the pencil in the loop as shown and draw a path allowed by the string loop. The path drawn will be an ellipse. The tacks locate the two focal points.

Copernicus thought that planetary orbits were circular. Kepler could not make Tycho's data fit Copernicus theory. The path planets actually travelled were always slightly off the circle. When Kepler realized that planets might have elliptical orbits around the Sun, he recalculated the new orbits, and the results fit within the measurements of Tycho's data.

Kepler described three laws of planetary motion. These laws of motion came from his painstaking study of Tycho's data.

- Planets travel in elliptical orbits around the sun but they are still pretty close to being perfect circles.
- If an imaginary line is drawn between the planet and the Sun, the line draws equal areas in equal intervals of time. This means a planet moves faster when it is close to the Sun and slower when it is farther from the sun.
- The third law is more complicated sounding, but shows the relationship between the average distance from the Sun and the time it takes a planet to travel around the Sun.

Kepler's work was a major breakthrough. For the first time Copernicus's model had been confirmed by careful mathematical analysis. Natural laws and mathematical principles were shown capable of describing nature. Kepler was bothered by not knowing **why** planets moved around the sun. It took a genius known as one of the great scientists of all time to give us the answer.

Online Resources

The following website provides information about Kepler and Tycho Brahe.

- University of Tennessee
  http://csep10.phys.utk.edu/astr161/lect/history/kepler.html

The following website looks at Kepler and Ptolemy and points out the difficulty of Ptolemy's model.

- University of Oregon
  http://zebu.uoregon.edu/textbook/planets.html

Isaac Newton

There is much to be said about Newton and his work, but for our purposes, you need to know one discovery he made. Newton was born in 1642, in Britain. During the 1660s, Newton was a student at Cambridge University, when the plague hit Europe. The universities were emptied of students, so Newton went home. During this time, he had ample opportunity to develop his ideas in physics and mathematics. The story goes that Newton was sitting in his garden and noticed an apple fall from a tree. He reasoned that whatever force pulled the apple down to Earth must be the same force as that which pulled planets to the Sun. From this humble beginning was developed the Law of Universal Gravitation and the force that pulled planets to the Sun was named the force of gravity.

Isaac Newton

The Law of Universal Gravitation states that all objects exert an attractive force on each other, no matter where they are located in the universe. The apple and Earth in Newton's garden exerted a force on each other, and the apple, because it is much smaller, fell downward a long distance, whereas Earth, because of its very large size fell an extremely small distance upward. Planets do not fall into the Sun as an apple falls into Earth because they move at quite high velocities that cause them to move sideways as they move down, resulting in movement around the Sun.

This law was important as it showed that natural laws that are in place at Earth's surface are the same as those in place throughout the universe.

Online Resource

The following website provides background information on Newton.

- University of Tennessee
  http://csep10.phys.utk.edu/astr161/lect/history/newtongrav.html

Learning Activity 4.6: Heliocentric Model

1. What two names are given to Ptolemy's model of the universe in this lesson?
2. Briefly describe Ptolemy's model of the universe.
3. Over what period of time was Ptolemy's model of the universe accepted as the correct one?
4. Why was Ptolemy's model accepted for so long?
5. How did Copernicus's model for the universe differ from Ptolemy's model?
6. Why wasn't Copernicus's theory readily accepted?
7. What stirred Galileo's interest in astronomy?
8. Why was Galileo able to reject Aristotle's assertion that air had no weight with such confidence?
9. How did the telescope allow Galileo to demonstrate that celestial objects were not perfect?
10. If Tycho Brahe had lived longer, why would he be disappointed with Kepler?
11. What breakthrough allowed Kepler to fit Tycho's measurements to Copernicus' heliocentric model?
12. Newton was able to satisfy Kepler's question, "What force moves the planets around the sun?" How did he do this?

Check the answer key.

Summary

The historical development of the geocentric (Ptolemic) model to the heliocentric (Copernican) model of the solar system is considered one of the great revolutions of scientific thought. The availability of information, tools, and other scientists' work allowed this transformation of thought to take place.

We should keep in mind that the works of Hipparchus and Ptolemy were not just simple ideas that were not as good as what came from the scientists following them. Their explanations formed a model that satisfactorily explained many aspects of planetary motion. The heliocentric model was, however, able to explain planetary motion with greater simplicity and Newton's Law of Universal Gravitation demonstrated the universality of the laws of motion that Aristotle didn't know existed.

Notes

LESSON 6: MODERN ASTRONOMY

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe the contributions of Sir William Herschel to modern astronomical science
- ☐ label a diagram of a refracting telescope
- ☐ explain why refracting telescopes are restricted to 102 centimetres in length
- ☐ label a diagram of a reflecting telescope
- ☐ explain why reflecting telescopes can be larger than refracting telescopes
- ☐ explain why reflecting telescopes larger than 510 centimetres are difficult to produce
- ☐ state the components of the electromagnetic spectrum and its importance to modern astronomy
- ☐ state two space mysteries created by radio telescopes
- ☐ state how we can "see" images from infrared and high-energy telescopes even though we cannot see that portion of the electromagnetic spectrum

Key Words

- observational astronomer
- Uranus
- Milky Way
- galaxy
- nebula
- refracting telescope
- objective lens
- eyepiece lens
- refract
- electromagnetic spectrum
- radio telescope
- pulsar
- quasar

Online Resource

The following website has information on all types of telescopes.

- Encyclopædia Britannica
  www.britannica.com/EBchecked/topic/430495/telescope

What do we mean by "Modern Astronomy"?

The term "modern astronomy" means much more than just activities related to space sciences in recent times. It refers to a whole change in focus of what astronomers were up to. For most of history, astronomy was done with the naked eyes only and with instruments to plot the positions of objects like stars and planets. The major work was about accounting for the positions of these objects and trying to understand their motions.

The work of Copernicus, Tycho Brahe, and Johannes Kepler—along with the ever present Galileo—pretty much sealed the deal on creating models of how objects moved. Isaac Newton's theory of gravitation provided a key insight into was actually was causing these motions. It was the telescope, though, that opened up new areas to focus on. For instance, the surface features of an object like the Moon were now accessible to human eyes. We could see moons around Jupiter and a ring system around Saturn. We were now able to actually explore what these objects were made of. Lastly, observing with telescopes allowed us to understand that distances in the universe were immense, and this provided a way to think about when and how the universe came to be.

Sir William Herschel

Sir William Herschel

William Herschel is regarded as the first of modern astronomers using the telescope.

After Isaac Newton connected a large number of ideas together, astronomy had become a modern science and could now open up many frontiers. The perfecting of new telescopes had a big effect on what could be observed and investigated.

Observing the natural world, applying the rules of mathematics, and testing hypotheses became one method by which models of the universe were developed. It was the telescope, though, that really set some new ideas in motion. What made astronomy "new" or "modern" was a shift in focus from trying to save outdated ideas to recognizing that the universe was huge and had evolved over long, long periods of time.

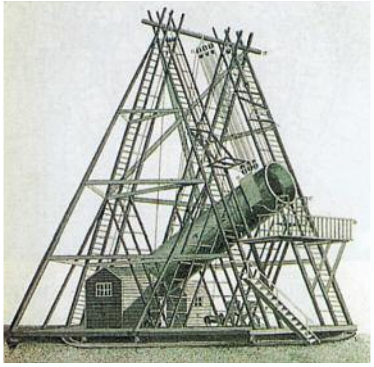
William Herschel was born in 1738, about 11 years after the death of Newton, in Hanover, Germany. In 1757 he travelled to England where he remained for the rest of his life.

Online Resource

The following website provides a number of biographies about Herschel.

- Wolfgang R. Dick
  www.astro.uni-bonn.de/~pbrosche/hist_astr/ha_pers.html

Herschel was a music teacher who loved to observe the heavens. Since Galileo's time, telescopes had become more and more common. By Herschel's time telescopes had come into common use. Anyone who had enough money could become an **observational astronomer**. Herschel spent as much time as he could observing the universe through his telescope. It was soon apparent that he required a better telescope, one that could show him the finest details of the Moon and planets. The only problem was that his income from teaching music was too small for him to afford one of the best telescopes. Herschel decided that the solution to his problem was to build his own telescope.



One of Herschel's Reflecting Telescopes*

After months of careful work, Herschel had completed a large curved mirror that was the main component of a reflecting telescope. His skill at producing large mirrors became so developed that he was soon producing the best telescopes in Britain.

On March 13, 1781, Herschel discovered an object in space that looked like a small green disk. He observed that the disk was moving slowly across the sky. Herschel concluded the object must be a comet and reported his conclusion to the Royal Society in London. It was determined later that it was not a comet, but rather a new planet. The discovery of a new planet beyond Saturn was a surprise to everyone at the time. Herschel became such a celebrity overnight that he was awarded a grant by the British King, George III. Herschel was now able to devote himself full-time to the study of

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*Photo Credit: George Bernard/Science Photo Library/Photo Researchers. Source: Lindenberg, Dawn, et al. *ScienceFocus 9: Science, Technology, Society*. Toronto: McGraw-Hill Ryerson, 2002. Figure 5.27. 385. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

astronomy. Herschel named the planet Georgium Sidus in honour of King George, but eventually tradition was followed, and it was named after a figure from Roman mythology—**Uranus**—who was the goddess associated with the heavens above.

Herschel wanted to study the motion of stars and the composition of the **Milky Way**. As he began counting stars, Herschel must have realized the enormous task he had set for himself. He devised a new way of counting called "star-gauging" in which he would section off small parts of the sky and count the stars in that section. In this way he discovered millions of stars with his telescope knowing that a better telescope would probably reveal millions more.

One of Herschel's island universes—the Andromeda Galaxy*

As he counted the stars, Herschel realized they clustered in such a way that he declared they formed "powder puffs" in space. Space scientists discovered later that Herschel was absolutely correct. Today, some of these "powder puffs" are called **galaxies**. Our "powder puff" is called the Milky Way. Our Sun is located near one of the outer edges of the Milky Way.

As he looked deeper into space, Herschel observed clouds of light which he interpreted as more groups of stars. Herschel called these clouds in the sky "island universes." These clouds had been observed by other astronomers and were called **nebulae**, which, not surprisingly, is Latin for "cloud." Herschel stated that some of these "clouds" could be other galaxies beyond our own Milky Way. Later, more powerful telescopes have shown that Herschel's inspired guess was correct. The work of Herschel and other scientists paved the way for modern space science.

Scientists from Galileo onward have been able to use the telescope to look farther into the heavens as this instrument has been refined and modified over the years. The telescope has also changed the way we "see." In addition to using visible light, telescopes can use different parts of the light spectrum to analyze objects in space.

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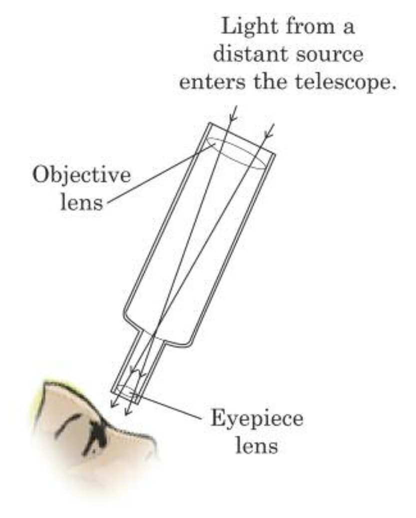
*Photo Credit: NASA/Robert Gendler. Source: Blake, Leesa, et al. *On Science 9*. Toronto, ON: McGraw-Hill Ryerson, 2009. Figure 9.15A. 378. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff.*

The Refracting Telescope

The earliest telescopes were refractor telescopes. Galileo's telescope was a primitive refractor, but it allowed him to see celestial objects in greater detail than was possible before. Galileo manufactured his own telescope in 1608. His telescope was capable of taking in 30 times the light compared to his eyes alone.



The Refracting Telescope

Astronomers experienced a problem with the early telescopes. A refractor telescope bends light as it enters the front **objective lens**; however, different colours of light **refract** (bend) different amounts. As a result, simple refractor telescopes produced a hazy ring of colour around the image. Eventually, a British astronomer found that by placing a carefully fitted lens with the objective (front) lens, the two lenses overcame the problem.

Astronomers wanted to look farther into space and see objects more clearly. Larger lenses in the telescope meant greater light gathering capability, allowing a close look at planets, moons, and stars. Producing a larger lens was a difficult task. As the light had to pass through the lens, there could not be any imperfections in the pouring of the molten glass or the grinding of the lens to form the correct shape. As a result, the practical limit to the size of an objective lens in a refractor telescope was four inches (approximately 10 centimetres) for many years. At the end of the nineteenth century, giant lenses were being built. The two largest to this day are 92-centimetre and 102-centimetre telescopes built in the United States. There are two restrictions to the size of the lens in refractor telescopes:

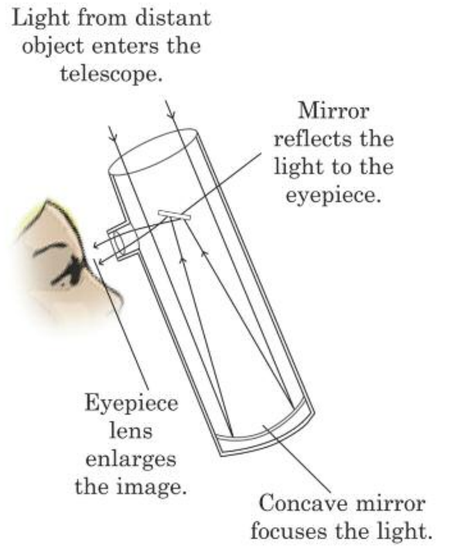
- Larger lenses cannot be built without imperfections in the glass.
- The lens becomes so heavy that it bends under its own weight producing a distorted image.

The 102-centimetre telescope at Yerkes observatory is extremely powerful, allowing a light gathering capability 40 000 times that which can be seen with the naked eye.

The Reflecting Telescope

Reflecting telescopes were first built in the 1600s. The refractor telescopes had problems with a coloured haze around the image. Astronomers looked for a solution in other telescope designs. One design that became popular is called the reflecting telescope.

The reflecting telescope was first constructed by Isaac Newton in 1668. Today, we often refer to this type of telescope as a *Newtonian reflector* because of its historical significance. A reflecting telescope has the advantage of using a concave mirror to gather light instead of a large objective lens made of glass. Mirrors are much easier to build than lenses as light reflects off the mirror instead of travelling through a piece of shaped glass. There is also the advantage that since the light does not have to pass through a glass lens, the problems that would be created by small imperfections in the glass can be avoided. Mirrors need to have a shiny, smooth surface that is easier to build. If you were to grind a lens for a refracting telescope, you would need TWO polished surfaces. Light travels into the telescope, reflects off the concave reflecting mirror, hits a flat mirror that reflects the light again through an **eyepiece lens** and then into the eye.

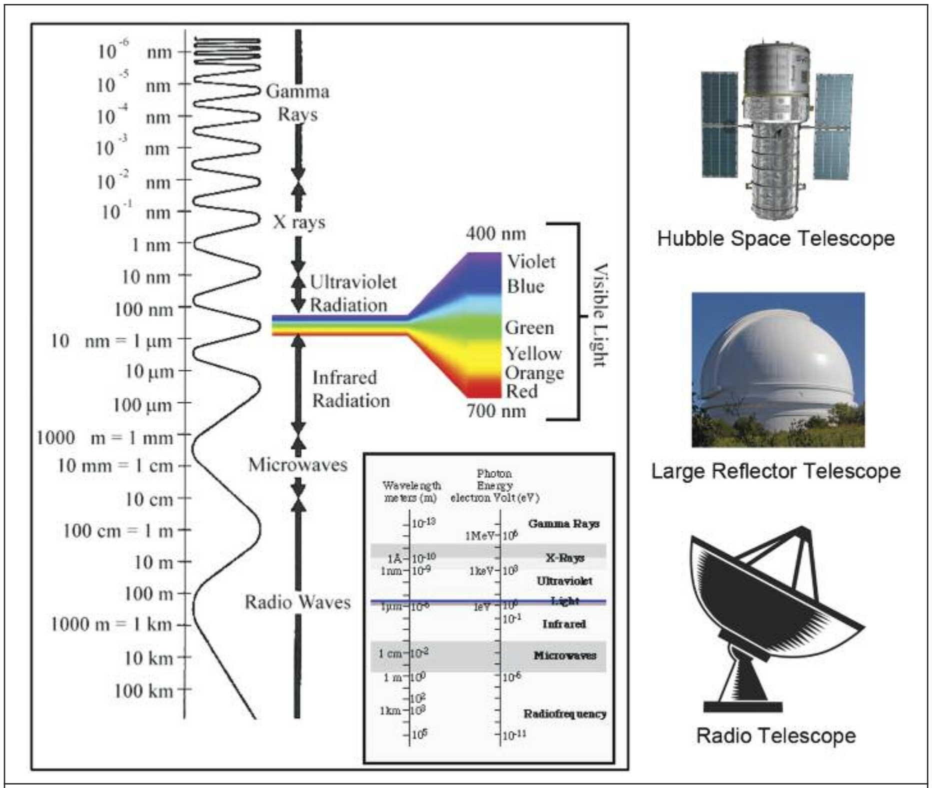


The Reflecting Telescope

Large reflecting telescopes were built as early as 1845 when Lord Rosse created a 184-centimetre mirror. One of the most famous reflecting telescopes is the 510-centimetre reflecting telescope located at Mount Palomar in California. The one restriction to building super large reflecting telescopes is the difficulty encountered when the glass making up the mirror is cooled down. The cooling process must be done carefully or the glass will crack. In order that the large reflecting telescopes can take advantage of their huge light gathering capability without the image being distorted by atmospheric conditions, they are constructed near the tops of mountains where the atmosphere is as clear as possible. These remote locations also help keep observers free from the glare and glow of city lights.

Radio Telescopes

You know that as you look at a star, you are looking at visible light that began its journey some time before you saw it. The light you see is only a small part of the whole spectrum of radiation produced by the star. The full spectrum of radiation is called the **electromagnetic spectrum**. The electromagnetic spectrum contains radio waves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays. Take a look at the diagram below, which relates the type of radiation to the size of the wave and to the sort of telescope that is used for imaging in that part of the spectrum. You will see that higher energy radiation (e.g., gamma rays from stars) tends to have very small wavelengths.



Electromagnetic Spectrum*

All parts of the electromagnetic spectrum travel through space at the speed of light, which is close to 300 million metres per second. Each section of the spectrum can be used to tell space scientists something about objects in space.

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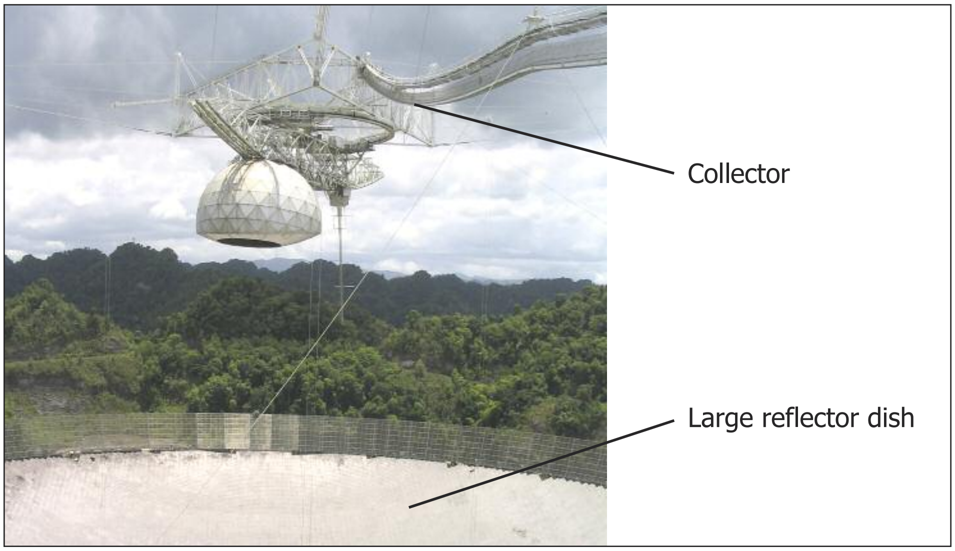
*Source: Brookshaw, Marcus. "Glossary: Electromagnetic Spectrum." www.upei.ca/~phys221/mbrookshaw/Glossary/complete_em_spectrum.JPG (17 June 2010). Reproduced with permission.

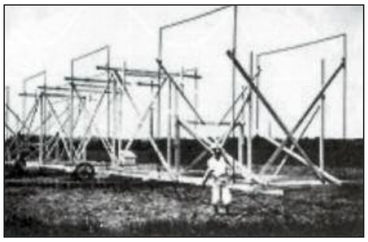
You have used a radio to listen to your favourite music. Scientists can do the same by using radio telescopes. The music listened to by scientists, however, is slightly different!

A radio telescope looks like a giant satellite dish that you might have connected to your TV. The giant dish reflects the radio waves to a collector located in front of the dish.



The largest single dish radio telescope in the world is the Arecibo Observatory in Puerto Rico.

Radio telescopes have been used to make some remarkable discoveries in space science. The first hint of radio wave activity in space came when a research engineer was doing some research in an attempt to eliminate static in radio transmission. The apparatus he used is shown below. In the process of picking up static, it also picked a steady hiss. The engineer, Karl Jansky, eventually realized he was receiving a radio signal from the Milky Way galaxy.



Karl Jansky's equipment was the first to pick up a radio signal caused by radiation coming from a star.*

Using Jansky's findings, an American, Grote Reuber, built a small radio telescope. He used it to find signals like those Jansky found from several different sources in different parts of the universe.

Radio telescopes have been responsible for some exciting discoveries that have answered some questions, but they have also created some puzzling questions. Radio telescopes have found some very distant objects that have produced unusually strong radio signals.

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*Source: Lindenberg, Dawn, et al. *ScienceFocus 9: Science, Technology, Society*. Toronto: McGraw-Hill Ryerson, 2002. Figure 5.34. 394. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

How could some object in space, so far away, produce such a strong signal? Radio telescopes were responsible for the discovery of neutron stars, some of which produce a varying signal made up of pulses of radio waves. These signals come from objects called **pulsars**, and were initially thought to have come from some alien civilization and caused great excitement in the scientific world for a time. Radio telescopes were used to detect **quasars**, offering science its greatest mysteries today. Quasars are celestial objects that look like stars, but they give off much more energy than a star. Quasars could be the product of colliding galaxies.

Online Resource

The following website provides more information about radio astronomy and radio telescopes.

- California Institute of Technology
  http://www2.jpl.nasa.gov/radioastronomy/

Radio telescopes located in the desert of Arizona are part of what is called the "Very Large Array" or VLA.*

Other Telescope Types

Infrared telescopes use the infrared portion of the electromagnetic spectrum. It is impossible to look through and see anything in these telescopes since our eyes are not sensitive to this wavelength on the electromagnetic spectrum. Some types of photographic film are sensitive to this wavelength and pictures can be taken which show images of objects in space detected by the telescope. Other telescopes detect high-energy radiation from stars. High-energy radiation refers to the X-ray and gamma ray portions of the electromagnetic spectrum.

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*Photo Credits: Left: Raphael Gaillarde/Gamma Liaison; Right: Rafael Macia/Photo Researchers. Source: Lindenberg, Dawn, et al. *ScienceFocus 9: Science, Technology, Society*. Toronto: McGraw-Hill Ryerson, 2002. Figures 5.37A and 5.37B. 396. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff.*

These telescopes work best in space as Earth's atmosphere has a scattering effect on infrared and absorbs the high-energy radiation. Satellites loaded with telescopes that were able to detect infrared and high-energy radiation have been sent into space, yielding spectacular results that promise to keep scientists occupied for years with their yield of experimental data.

The **Hubble Space Telescope**, which is in long-term orbit around Earth, is yielding images that have incredible clarity. You can look at Hubble Space Telescope images using the Internet address shown in the Online Resources section at the beginning of the lesson.

Learning Activity 4.7: Modern Astronomy

1. What event in Hershel's life allowed him to pursue astronomy full-time?
2. What system did Hershel use to count stars?
3. What name is given to Hershel's "powder puff"?
4. What were the hazy patches of light seen by Hershel and other astronomers called?
5. What celestial objects made up the hazy patches of light?
6. Do some research on the electromagnetic spectrum. Use books and the Internet as your sources.
   a. Draw a diagram of the parts of the electromagnetic spectrum and use the following terms to label the diagram:
      microwaves, *radio waves*, *gamma rays*, *visible light*, *infrared radiation*, *ultraviolet radiation*, *X-rays*
   b. Label the ends of the spectrum with the labels "highest frequency" and "lowest frequency."
   c. Label the ends of the spectrum with the labels "longest wavelength" and "shortest wavelength."
   d. At what speed through space will the following travel?
      Radio waves: ______________________________
      Visible light: ______________________________
      Gamma rays: ______________________________

continued

Learning Activity 4.7: Modern Astronomy (continued)

e. Which type of electromagnetic radiation would you use the following telescopes to view?

Reflecting telescope: ______________________________

High-energy telescope: ____________________________

Radio telescope: __________________________________

Check the answer key.

Summary

William Herschel ushered modern space science in as he made and used bigger and bigger telescopes with optical clarity that challenged the best telescopes in the world at the time. Herschel discovered a planet, the first with a telescope, and turned his attention to space beyond our galaxy. Deep space was a mystery being explored as Herschel began seeing new shapes that he called powder puffs, but which became known as galaxies. Herschel observed nebulae, the birthplace of stars. Herschel also gave us a new appreciation for the vastness of space as he began to count stars and to record how many there actually were even in just our own galaxy.

To retell our story of what we mean by modern astronomy, it is now important for us to realize that astronomy is more than simply wanting to explain how the night sky appears to us, and what motions objects like planets are capable of. We are now trying to understand the makeup and size of these objects and to develop a better idea of how the universe has unfolded since its beginning.

For instance, at the beginning of the twentieth century, people such as Harlow Shapley were putting together ideas that shaped our understanding of how the Milky Way Galaxy is arranged. Then, along came the work of Sir Edwin Hubble—yes, the telescope in Earth's orbit is carrying his name—who was able to build on that earlier work and show us that the universe was much larger than we previously thought, and still expanding. Today, we have enough evidence to believe that the universe is at least 10 times larger than even Hubble supposed it to be.

By putting telescopes into space, we are now free from the effects of Earth's atmosphere and the cycles of day and night that restrict observations down where we are. By having the ability to "see" backward in time over the vast distances of space, it is like a form of time travel. When we look at an object such as the Andromeda Galaxy (see picture below), we are seeing light from stars that began its journey to our eyes over *two million years ago*! And so, a telescope is not just an instrument that takes pretty pictures of objects scattered across the vast reaches of space, it is also a sort of *time machine*.

The Andromeda Galaxy, which is at a distance of about 2 million light years from Earth.*

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*Photo Credit: NASA/Robert Gendler. Source: Blake, Leesa, et al. *On Science 9*. Toronto, ON: McGraw-Hill Ryerson, 2009. Figure 9.15A. 378. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

LESSON 7: CELESTIAL NAVIGATION

Lesson Focus

After completing this lesson, you will be able to

☐ describe briefly how navigation using the Sun and stars first got started
☐ describe what a constellation is and how it is useful to navigate by
☐ describe the significance of latitude and longitude
☐ describe how latitude and longitude are measured
☐ describe how latitude and longitude are used
☐ describe the tools of navigation that use the stars as guides

Key Words

- constellations
- latitude
- North Star
- Polaris
- cross-staff
- backstaff
- sextant
- longitude
- prime meridian
- chronometer

Online Resources

The following websites provide information about celestial navigation.

- PBS
  www.pbs.org/wgbh/nova/longitude/secrets.html
- Rice University
  www.ruf.rice.edu/~feegi/astro.html
- Encyclopædia Britannica
  www.britannica.com/EBchecked/topic/407011/navigation

Early Navigation

The need to travel from one place to another became important as ancient cultures gathered into larger groups and settled in towns. The need for food was satisfied when hunters would leave a settlement, hunt their food, and easily return to their home because they would have remained in familiar territory. As the need for trade with other cultures became important, travel would take people much larger distances away from their home. Overland trade was still relatively easy since the travellers would use well-established routes that were easily followed.

Societies located on the edge of water would logically want to use the sea (or rivers) as their transportation route. Initially, boats would travel within sight of shore. In this way they could fish and carry on commerce with other groups within short distances. Familiar landmarks such as rocks or shallow areas could have been used to mark locations and routes back and forth from home base. The sea left no trail as land travel did; as a result the landmarks would be memorized and transmitted from one generation to the next. Using sighted landmarks could be dangerous for sailors if the sightings were lost or obscured by fog or sudden storms. Even with these restrictions placed on them, sailors were able to establish trade routes to distant ports.

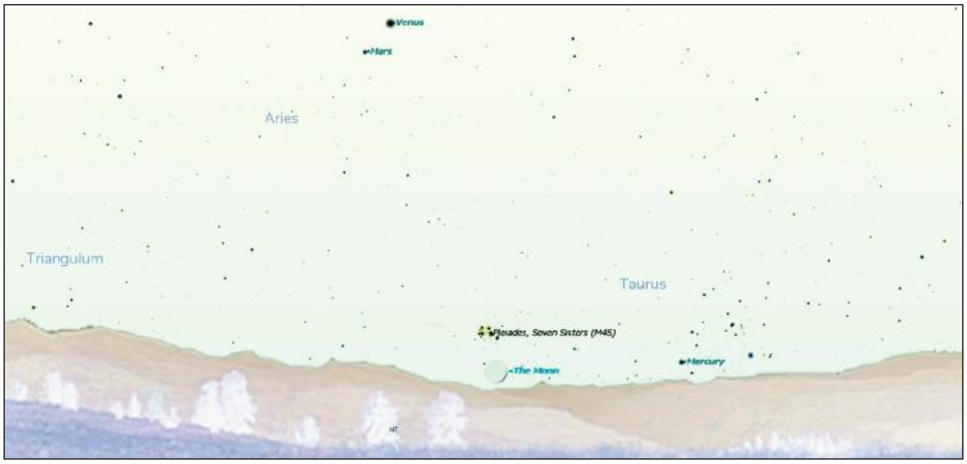
Some nations able to travel large distances include the Phoenicians and Egyptians. The nations that were able to successfully navigate over water were able to conquer other countries, in addition to trade with them, thereby increasing their power, influence, and wealth.

Seafarers began to associate celestial objects with navigating their ships. They noticed different shapes of star groupings called constellations, which they could memorize and use as indicators from which they could determine the direction they were heading. Gradually stars and the Sun became the "landmarks" used for navigation.

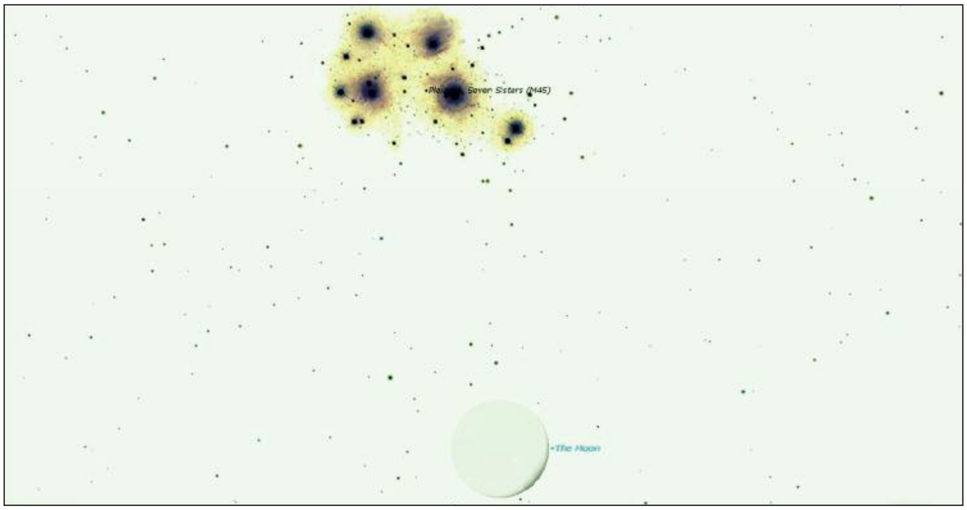
Constellations are groups of stars that were recognized early in the history of civilization. The Phoenicians, for example, identified and named most of the constellations we know today, and they did it 4000 years ago. The names given the constellations by nations often differed but they were usually named after gods or animals that were known to them. The constellations can be called signposts as they point to different parts of the sky and help identify star positions.

The change from remaining within land view to travelling across oceans had a profound impact on travel, trade and exchange of ideas. Men could now travel huge distances with little effort. There was constant trade taking place between Egypt and the island of Crete, a distance of 500 kilometres, on a regular basis around 2500 BCE. By 600 BCE, Phoenicians were importing tin from Cornwall, England. The Vikings had established routes to England, Greenland, and even North America by the tenth century. Polynesian seafarers, considered the best in the world, were able to emigrate to many new places all the way from the Marquesas islands to Hawaii, a distance of 3700 kilometres, by 400 CE.

One interesting example of how a celestial ("in the heavens") event can both guide travellers at sea and become part of cultural heritage comes to us from the people who first colonized what is now Aoteoroa—New Zealand. The new year for these people—known as Matariki—arrived when the star cluster we know as the Pleiades was seen exactly in the east along with the crescent Moon. See the images below (the pictures have been inverted to make them easier to see the stars and the Moon).



The crescent Moon and the Pleiades cluster that marks the New Year—Matariki—in New Zealand among the Maori people.
Graphic courtesy of Starry Night®/Starry Night Backyard, Version 4/Imaginova® Corp.



Closer view (as if in 10x50 binoculars) of the crescent Moon and the Pleiades cluster that marks the New Year—Matariki—in New Zealand among the Maori people.
Graphic courtesy of Starry Night®/Starry Night Backyard, Version 4/Imaginova® Corp.

The recorded history of methods used by ancient travellers navigating long distances is sketchy and sometimes doesn't exist at all. In any case, it is obvious from the records we do have that they used the Sun and the stars as navigational tools. We know that Arab peoples also used poetry in addition to traditional astronomical thinking; Polynesians and Micronesians used songs and poetry to remember their elaborate star charts as well as to recall different types of wave swells, ocean currents, and smells to track their progress across thousands of kilometres of ocean. Learning large amounts of information needed for navigation meant these nations would begin training future sailors when they were children.

With all the knowledge possessed by these cultures, however, they did not know how to navigate scientifically. As long as the conditions were predictable, as long as the winds kept blowing in a direction that was favourable, there were no problems. If there were unpredicted storms or periods of prolonged calm, the navigators could be in trouble. The scientific method of navigation allowed mariners to travel anywhere in the world and come back.

Homer, the Bible, and Norse traditions all described the Sun and stars as navigational aids. Early in the history of navigation there is a distinction made between the direction in which the Sun rises (Asu) and sets (Ereb). The direction for north could be determined by the direction the Sun casts a shadow at noon, and south is the opposite direction. At night, the stars rise in the east and set in the west as a result of Earth's daily rotation once each 24 hours. This is basic information, but it allowed travellers in the early civilizations a sense of direction. A traveller could determine his or her direction by observing the position of the rising Sun, or the position of his or her shadow at noon.

Determining Latitude

Ships needed a method of navigation that would allow them to precisely locate their position without depending on landmarks.

When you stand at the same spot and look at the **North Star**—which is also named **Polaris**—you will observe that its position never changes. Navigators based their direction on the North Star (Polaris) remaining in much the same position in the sky all the time in the Northern Hemisphere.

If you travelled in a north-south direction, Polaris would appear higher or lower in the sky. Navigators also notice that Polaris would sink lower in the sky as they approached the equator until it disappeared as the ship passed the equator. Conversely, navigators would observe the North Star higher in the sky as they travelled toward the North Pole and eventually if they arrived at the pole, Polaris would be directly overhead.

If you were able to take your camera to the North Pole in the middle of winter and hold the shutter open for 24 hours, in the resulting picture, you would see Polaris as a bright pinpoint of light with other stars forming circles of light around it. You would choose winter to take the picture in order to get 24 hours of darkness.

If a sailor wanted to know where he was between the equator and the North Pole, that is, if he wanted to know his latitude on the earth's surface, he just needed to know the number of degrees the North Star was above the horizon. The latitude could have been measured using the hand method you learned in Lesson 2. If the navigator of a ship observed that Polaris was always five fists above the horizon, he would know they were travelling on the same latitude. In some cultures, different types of sticks could have been notched for the navigator to measure the position of Polaris more easily and accurately.

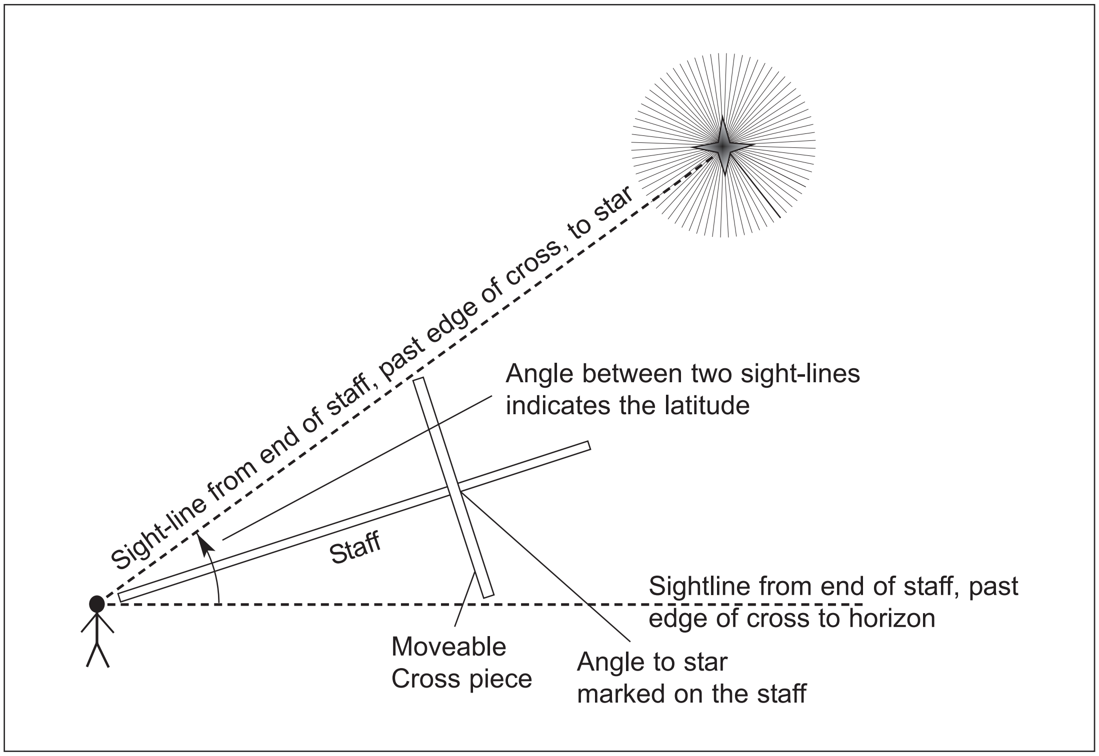
Latitude is the name given to mark a position between the equator and the North Pole. The equator is given a latitude of 0 degrees and the North Pole is given a latitude of 90 degrees. Latitude lines are shown on a map or globe as horizontal lines drawn every 10 degrees. A navigator would use his instrument to determine a ship's latitude and therefore its position between the equator and the North Pole.

Gradually the tools for measuring latitude became more accurate and more complex. The astrolabe that you built in Lesson 2 was modified slightly to allow sailors to measure the angle to Polaris or the sun. The astrolabe allowed a very accurate measurement to be taken.

Another tool often used by mariners was the cross-staff. The cross-staff was made of a stick (staff) about three feet long fitted with a cross that could slide back and forth on the staff. The staff had angle markings on its length. The navigator would look at the object, Polaris or the sun usually, with the cross adjusted to sight from the end of the staff to the cross end piece to the star. The navigator at the same time would sight from the end of the staff, along the opposite end of the cross to the horizon.

Cross-Staff

The cross-staff was the most commonly used navigational tool until the eighteenth century. There was a drawback to the use of the cross-staff. The sun was used to determine latitude at noon, requiring the navigator to look into the sun. Many navigators would likely have damaged their eyes, or even accidentally lost their eyesight, as a result of doing these measurements many times over many years.



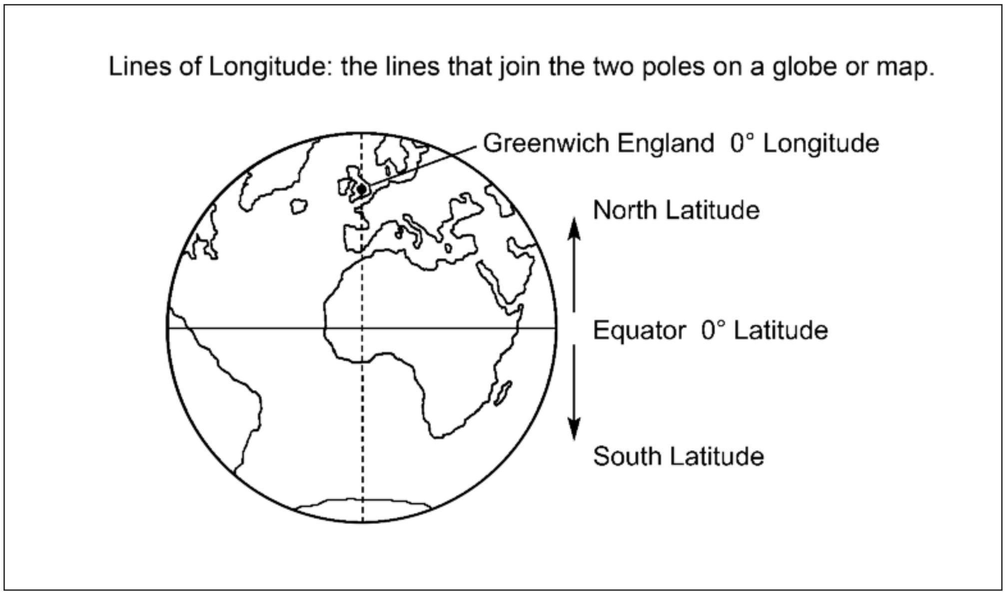
In 1594, an English navigator, John Davis, developed an instrument called a **backstaff**, which allowed the observer to place his back to the sun and safely make latitude measurements.

The **sextant**, the final type of mechanical tool for determining latitude, was developed in the middle eighteenth century and was used until modern technology made it irrelevant. The sextant used two mirrors, which reflected the horizon and a star or the Sun. The navigator adjusted the sextant until the star and horizon superimposed on each other. The sextant did not need to be lined up with the horizon, which was difficult in rough seas, it did not require the navigator to look into the sun, and the measurement could be performed quickly. The sextant could measure the latitude to within several hundred metres in any kind of sea, making it a prized tool for navigators.

The Need for Finding Longitude

European navigation became more accurate during the sixteenth to nineteenth centuries as the instruments for measuring latitude became more refined and easier to use. In order that a navigator knew where the ship was located, he needed to know the second coordinate, that is, the **longitude** of the ship. In addition to knowing both latitude and longitude, the navigator needed maps to know where on the map the ship's coordinates placed them.

Longitude measures the distance—in **degrees east or west**—of the prime meridian. This prime meridian (or zero degrees longitude) is located at Greenwich, England. Longitudinal lines are the vertical lines that are usually spaced every 10 degrees on a map or globe. A navigator who knew both latitude and longitude would have a precise set of coordinates that would show him where the ship is located. When you look at a map or globe with latitude and longitude marked on it, the lines form a grid over its surface. The sketch below will assist us in thinking this through.



There was an attempt to determine longitude by using measurements of the Moon, but they proved impractical and inaccurate for several reasons. The calculations were long and complex making errors in computation common; as well, there were still no accurate lunar tables.

The British government offered a prize of £20 000 (pounds, or about $40,000 in Canadian money) to anyone who could devise a way of determining longitude while at sea. The size of the prize money indicated just how difficult a problem it was to solve. The Longitude Prize attracted scientists from around the world as they competed to find an accurate clock and claim the prize. As you can imagine, it also attracted the lunatic fringe, including a series of weird and wonderful proposals such as “sympathy powder.” One slightly eccentric entrant claimed that if a knife were dipped in sympathy powder and then used to inflict a wound on a dog, the dog would experience sympathy pain every time the knife was thrust back into the powder. Thus, if the dog were placed aboard a ship set out to sea and the knife was dipped into the powder at exactly noon Greenwich Time then the dog would yelp on the ship indicating when to measure time. Needless to say, the prize remained unclaimed.

The now famous painter, William Hogarth, included the insane people who were searching for the solution to the Longitude Prize in his sketch, *The Rake's Progress in the Madhouse.* Among the inmates in the Bedlam insanity hospital (these were called "asylums" years ago), can you locate the ones who had gone mad looking for a solution to the longitude problem?

Seafarers had known for some time they could measure longitude if they had a clock that would tell them time at a known spot. Eventually, John Harrison invented the chronometer and he won the prize. A chronometer is an extremely accurate clock that could be placed on a ship and used to measure the precise time.

Longitude could be determined by comparing the time at the prime meridian (0 degrees longitude) with the time on the ship. The time on the ship could be determined several ways. Noon could be easily measured off the Sun by marking the time when the shadow from the sun pointed due north. The time at the prime meridian was measured on the chronometer.

The prime meridian is the place from which all longitudes are measured and from which all time is compared. The prime meridian was chosen to be located at Greenwich, England in deference to England's power as a seafaring nation at the time. If you look at a globe, you will see that zero time and zero longitude is chosen as a longitudinal line that passes through Greenwich, England. Any ship from this time onward would know exactly where they were located as long as they had a sextant and a chronometer on board.

As navigational technology was advancing, cartographers (we call them "mapmakers") were also carefully charting coastlines and land surfaces, gradually marking the latitude and longitude on these maps. Cartographers were in attendance on many trips. Their careful work set the foundation for a navigator to know where he was located, when he was approaching land, and what route would best suit the purpose of the voyage.

The principles for navigation that you have learned are just as effective if you are flying an airplane or driving a car. The methods of determining latitude and longitude are much more technologically advanced nowadays and therefore faster, as they must be on an airplane, but fundamentally, they are the same measurements.

In addition to maps, charts of the stars were also needed.

Other Navigational Aids

Even the earliest navigators used aids to help them in their task of getting to the right place.

One of the earliest tools we know of measures depth of the water below the ship. Egyptians from 1600 BCE used poles; Vikings used lead weights on a string. As they pulled the string in, they would use their outstretched arms as a distance (called a fathom) to measure the depth of the water. The nautical term to measure the depth of water is still called a fathom in some parts of the English-speaking world.

All ships must have running lights and foghorns to prevent collisions at sea. A red light runs at port and a green light at starboard with a bright white light in the middle. Bells used to be rung in fog; now foghorns replace them.

Learning Activity 4.8: Celestial Navigation

1. Early seafarers used navigational aids other than stars to help find their position.
    a. Name two navigational aids used.
    b. Why were the early ships often limited in their navigation?
    c. What were some of the dangers associated with early navigation?
    d. How were landmarks transmitted from one generation to the next?
2. Why is it necessary to use latitude and longitude when travelling far away from familiar territory?
3. What does latitude measure?
4. What does longitude measure?
5. Use an atlas to determine the approximate latitude and longitude for The Pas and Brandon.

continued

Learning Activity 4.8: Celestial Navigation (continued)

6. What is the longitude measurement at Greenwich, England?
7. What two time measurements are needed to determine the longitude of a ship at sea?
8. Try to determine the latitude and longitude of the place where you live.

Check the answer key.

Summary

Methods of navigation were developed as cultures expanded farther away from home cities and interacted with faraway civilizations. Travel by water, without any landmarks to offer guidance, required travellers to look to the skies and use celestial bodies, including constellations, as the signposts in their journeys. The next lesson will explore the travel of celestial objects around the Sun.

Learning Activity 4.9: Self-Quiz 1

You can use this learning activity (together with Learning Activity 4.12 and Learning Activity 4.14) to test your knowledge of concepts within this module.

Matching.

1. Match the name of the person in the right column with the most appropriate phrase in the left column.

   Greek astronomer who

   _____ moved away from using mythology to explain natural occurrences.

   _____ developed the concept of a celestial sphere.

   _____ was first to put forward a sun-centred model of solar system.

   _____ used a series of epicycles to explain retrograde motion of planets.

   _____ developed a huge star chart complete with categories of star brightness.

   _____ is considered to be the first to present mathematical evidence that planets orbit the Sun.

   _____ was first to use a telescope to observe the planets and moons.

   _____ developed the laws of planetary motion.

   _____ developed the Law of Universal Gravitation.

   _____ is regarded as the first of the modern astronomers.

   a. Aristotle
   b. Aristarchus
   c. Ptolemy
   d. Copernicus
   e. Kepler
   f. Galileo
   g. Herschel
   h. Newton
   i. Hipparchus
   j. Thales

continued

Learning Activity 4.9 (continued)

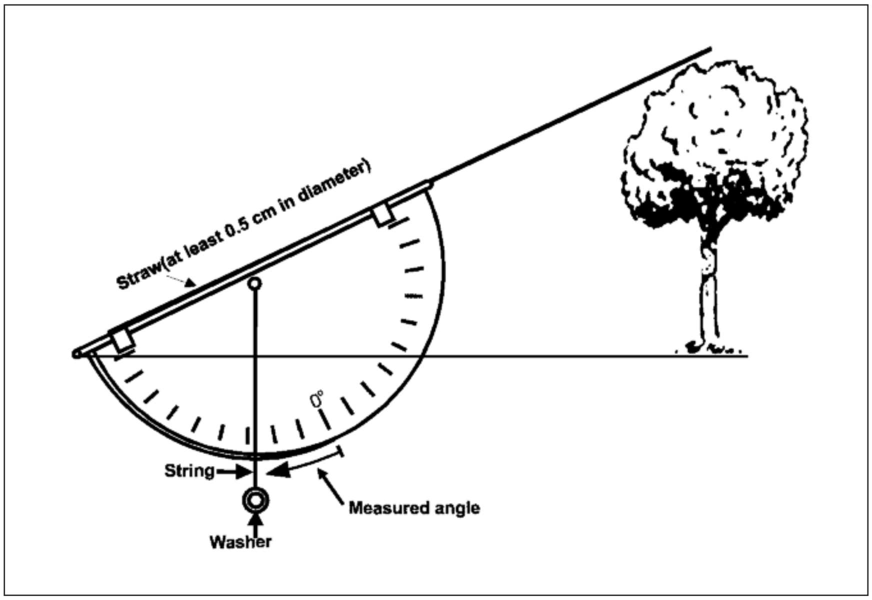
Fill in the blanks.

2. a. Ancient astronomers observed the wandering motion of some objects in the sky and called the objects ______________________.

   b. A student measured a planet at one fist above the horizon. What is the approximate angle the planet makes with the horizon?

   ____

   c. The astrolabe below makes an angle of ________° when measuring the height of the tree.



   d. Herschel discovered a new planet and named it Georgium in honour of the king of England, but everyone now calls the planet ______________________.

   e. Our galaxy is given the common name ______________________.

   f. Aristotle believed the space between planets, Sun, and stars was filled with a substance called ______________________.

Check the answer key.

LESSON 8: MOTIONS OF CELESTIAL OBJECTS

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe the significance of retrograde motion, and how the motions of certain planets such as Mars influenced models of the solar system
- ☐ explain how both the heliocentric (Sun-centred) and geocentric (Earth-centred) models can explain retrograde motion correctly
- ☐ from accessed data, plot on a star chart the positions of Mars over a period of a "retrograde loop" and account for this "apparent" motion
- ☐ explain, using your star chart plot, why retrograde motion is often referred to as "going backwards against the background stars"

Key Words

- orbit
- retrograde motion

Retrograde Motion

Do you remember from an earlier lesson how Ptolemy's description of the motion of planets in a geocentric system was a model that provided a reasonable but complicated description of the motion of planets? Is the heliocentric model any better at explaining the motion of planets?

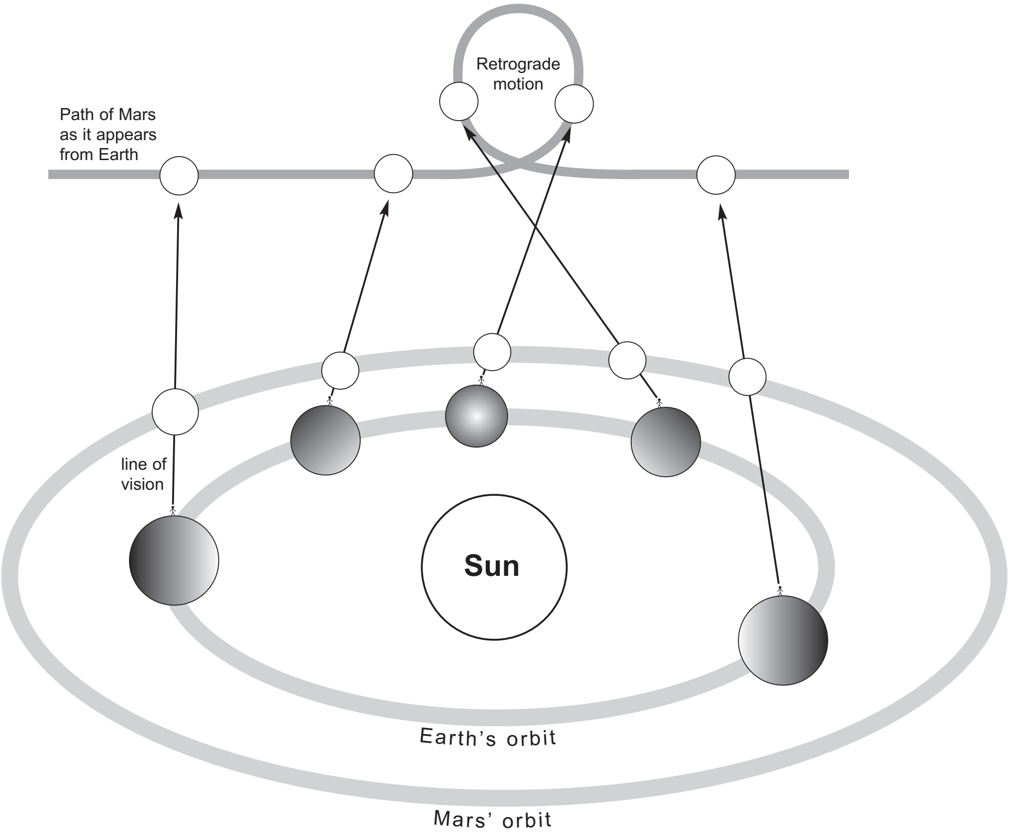
Let's go back to the observations that ancient sky watchers made thousands of years ago. These ancient astronomers likely watched the movement of bright objects in the sky that shined with steady light—they did not "twinkle"—and because of their motion when compared to the stars (which did not seem to move at all) named them planets which meant wanderers. The Greek word that this comes from is *planetos*. These planets, as they are still called today, revolve around the Sun along predictable paths we call **orbits**. We, living on spaceship Earth, also revolve around the Sun. The motion of some other planets, as seen from our perspective, seems to be quite ordinary until sometime during the year they begin travelling backwards for a while. After the backward motion stops, the planet proceeds onward and appears to behave "normally" again. The backward motion just described is called retrograde motion. This is a scientific term that describes any sort of motion that goes in the opposite direction to what we would expect.

Online Resource

The following website provides information about retrograde motion.

- La Salle University
  www.lasalle.edu/~smithsc/Astronomy/retrograd.html

The diagram below shows how the **heliocentric model** can explain the retrograde motion of Mars as seen from the same spot on Earth over a period of time. Notice Earth has gone through approximately one-half of a revolution around the Sun, while Mars has travelled about one-third of a revolution around the Sun. The five positions in the diagram show how someone looking from Earth to Mars would observe the motion of Mars against the backdrop of the stars.



Notice that retrograde motion in the diagram shows that we think of retrograde motion in terms of something like a planet moving in a “loop” against the background of stars. For instance, we see Mars from Earth and can determine that its moving backwards or forwards occurs because of our point of view in relation to the stars.

Notice that as the observer looks at Mars, he or she will see it travel normally for a period of weeks, and then it seems to come to a stop. Following that, Mars begins its retrograde motion as shown in the section of the diagram where it moves the other way. After the retrograde loop has finished, the planet appears to travel normally again—and for astronomers, they will say that “normal” motion is steadily moving towards the east a little bit each night. The retrograde motion of Mars—as viewed from Earth—can be easily explained using the heliocentric solar system model because it does not rely upon giving a planet another motion in addition to going around the Sun.

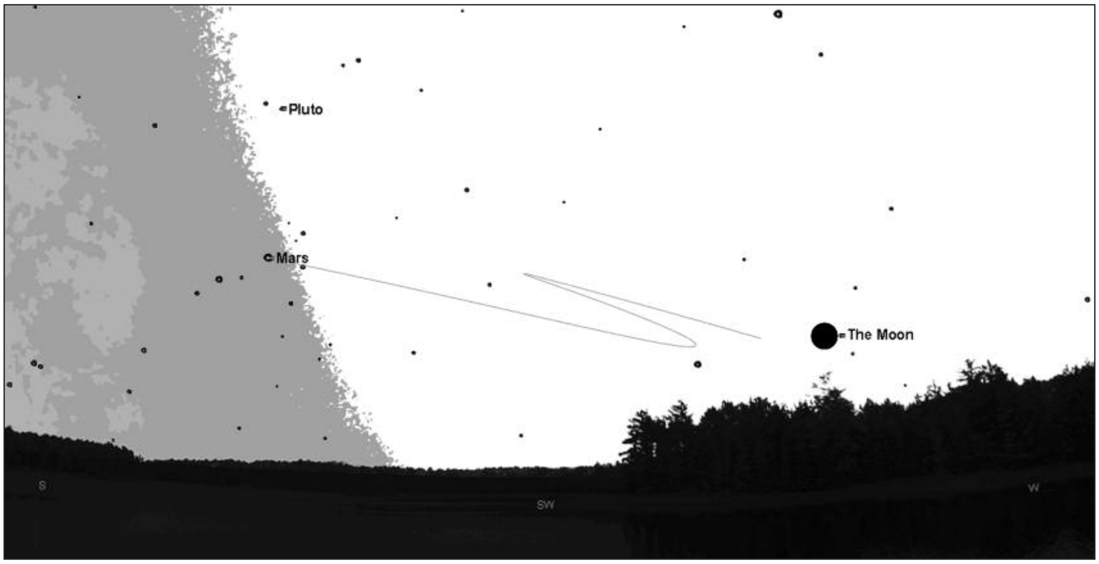
Notes

Assignment 4.4: Monitoring the Retrograde Motion of the Planet Mars (11 marks)

Background Information

The image below is a representation of the movement of the planet Mars over an 18-month period during 1988. Every 17 years, Mars's retrograde motion is easily visible to Earth observers. Although this phenomenon can always be seen, it is best observed when Earth and Mars are at their closest approach.

Star Chart



Graphic courtesy of Starry Night®/Starry Night Backyard, Version 4/Imaginova® Corp.

The motion of Mars as observed from Earth can be described using a race analogy. Imagine two runners named Tellus (the Earth) and Areos (Mars) who are racing around a track that is almost perfectly circular. Rather than allowing Areos (the outside runner) to start the race further along the track than Tellus (the inside runner), the two runners start side by side. Since Tellus can run faster than Areos (because he is closer to the Sun), Areos quickly begins to fall behind. As Tellus gains on Areos, there will be a short period of time where it will appear as though the outside runner slows down, stops momentarily, and then goes backwards. This is only an illusion, of course, as both runners are always travelling forward around the track.

continued

Assignment 4.4 (continued)

The star chart on the previous page shows where Mars appears to slow down, then stops, and reverses direction for a brief period before resuming its normal movement across the sky. We now call this **retrograde motion**. In the observational activity that follows, you will be plotting some data in order to examine something that was a very difficult idea for ancient astronomers to explain.

Take a closer look at the Star Chart on page 91. Could you describe—using your earlier work on **altitude and azimuth**—how these change over a period of five months for Mars?

Purpose:

To monitor and record the motion of Mars over time to better understand retrograde motion.

Procedure:

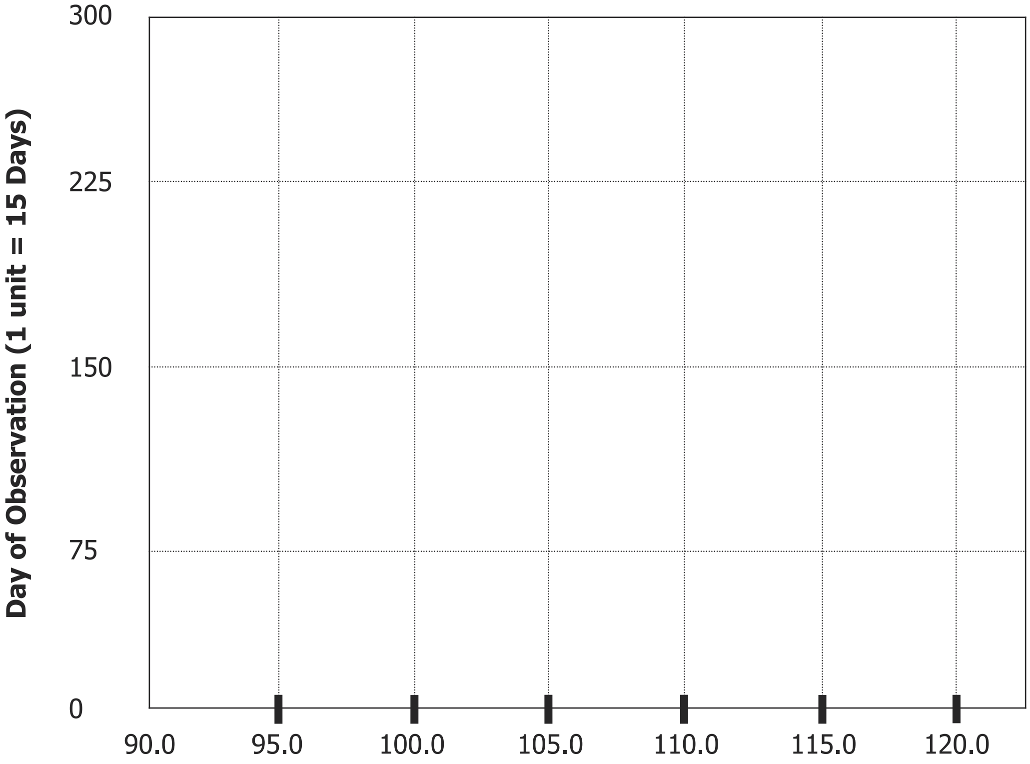
Imagine that the data set that appears below was taken from a student's logbook based on the star chart that appears along with the data.

1. Plot each position carefully on the blank graph on the next page. Label each point you plot with the date of the observation to better simulate these actual measurements. Join all of the points with a smooth line as best you can.*(8 marks—see graphing rubric from Lesson 4)*

Date of Observation	Azimuth of Mars
July 1	113.0°
July 15	105.0°
August 1	98.5°
August 15	94.0°
September 1	94.0°
September 15	94.0°
October 1	98.0°
October 15	102.0°
November 1	109.0°
November 15	109.0°
December 1	101.0°
December 15	95.0°
January 1	90.0°

continued

Position of Planet Over Seven Months of Observation



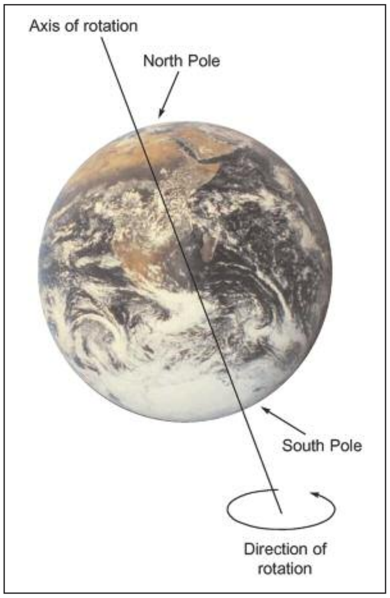
2. How does your plot compare with that of the positions of Mars on the star chart? Identify one difference and one similarity. *(2 marks)*

3. Circle the section of the graph that would represent the retrograde loop. *(1 mark)*

Notes

Earth in Space

The diagram to the left illustrates Earth, as it would appear in space. The axis around which it rotates is at an angle. Earth rotates on its axis once every 24 hours. Notice Earth rotates in a counter-clockwise direction, as viewed from above, which explains why the Sun appears to rise in the east, travel across the sky, and set in the west. Earth also revolves around the Sun. At times the North Pole is pointed towards the Sun, and we experience summer in the Northern Hemisphere. Six months later, we are on the opposite side of the circle of revolution from the sun, and we experience winter at this time. Note Earth does not wobble on its axis in order to point towards the Sun; instead, Earth points in the same direction all the time. It is just a characteristic of travelling in a circle around the sun that the angle of Earth in relation to the Sun changes.



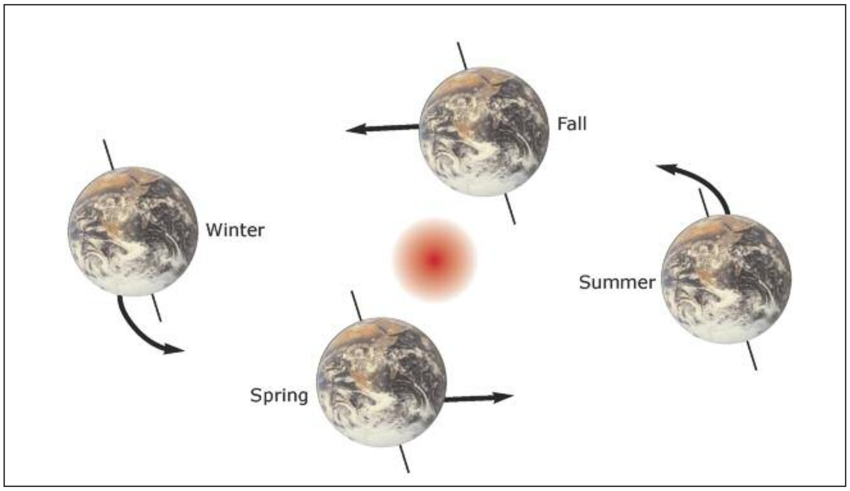


Diagram Showing Earth in Four Positions around the Sun

Notice the Northern Hemisphere is experiencing summer on the right side and winter on the left. Notice also Earth is angled the same direction on both parts of its orbit, but in summer in the Northern Hemisphere, the North Pole is angled toward the Sun and in winter the North Pole is angled away from the Sun.

Summary

Ancient civilizations all developed their own understanding of their origins. The motion of celestial objects in the sky was likely connected to their mythology or religious practices, resulting in stories that are unique to the culture from which they came.

The collection of celestial information, starting with Egyptian culture and including the Greek, Arab, Chinese, Polynesian, and American First Nations communities, was extremely accurate. A good example on this is the amazingly precise alignment of the base of the Great Pyramid in Egypt with certain stars on the north horizon.

The heliocentric model took thousands of years to be developed and eventually accepted as factual. It was the ability of this sun-centred model to adequately explain the motion of planets and stars—including retrograde motion of planets—that made it such a powerful way of viewing the cosmos. In a Sun-centred solar system, for instance, the motion of Earth around the Sun (revolution) provides a simple model to explain the 365-day year and the changes of the seasons.

Assignment 4.5: Assignment 4.5: Life on Mars (10 marks)

1. If you were going to construct a calendar for a civilization on Mars, what are the first celestial measurements you would want to make? *(2 marks)*

2. You spent a number of "Martian days" recording the position of the setting Sun (that would be **azimuth** readings). When looking over your data you discovered that the time it took the Sun on Mars to set at its farthest point north to its farthest point south was 344 days. How many days are there to a Martian year, then? Explain. *(2 marks)*

continued

Assignment 4.5 (continued)

3. Describe how seasons are produced in the Northern Hemisphere. *(4 marks)*

4. State and explain one reason for accepting the heliocentric model (Sun at the centre) explanation of retrograde motion. *(2 marks)*

LESSON 9: MEASURING SPACE

Lesson Focus

After completing this lesson, you will be able to

☐ define and calculate distances measured in astronomical units and light years

☐ determine distances using triangulation

Key Words

- astronomical unit
- light year
- triangulation
- parallax

Online Resource

The following website provides an explanation of measuring distances by the techniques of triangulation and parallax.

- Bucknell College of Engineering
  www.eg.bucknell.edu/physics/astronomy/astr101/specials/parallax.html

Introduction

In Sir William Herschel's time (he is the one who discovered the planet Neptune), around the middle of the eighteenth century, the reflecting telescope hinted about the true size of the universe but scientists thought the universe was contained within our own galaxy, the Milky Way. With newer technology, Edwin Hubble, in the early twentieth century, was able to demonstrate there were countless galaxies large distances beyond our own.

The number of galaxies is so large that we find the number difficult to understand. It is possible there might be 100 billion galaxies and each one of these galaxies might contain 400 billion stars.

Astronomical distances are extremely large, making it difficult to relate to them. If we were to use the common units for measuring distance on Earth, units such as kilometres and miles, the measurements would lose their meaning. Scientists have developed terms that help us describe distances in space that do not use such large numbers.

The Astronomical Unit (AU)

The astronomical unit is based on the average distance from Earth to the Sun. The distance from Earth to the Sun is 155 million kilometres. The same distance is 1 AU using astronomical measurement. Using Earth = 1.0 AU is a convenient measuring stick to use so that we don't have to use huge numbers by measuring distances in the galaxy using kilometres. Pluto—which in recent years is considered a "dwarf planet"—travels in an elliptical orbit (slightly oval shaped), and so can be as far away as 49.3 AU from Earth and as close as 29.6 AU to Earth.

The following is a list of the planets and their average distance from the Sun as measured in Astronomical Units (AU):

Mercury	0.39 AU
Venus	0.72 AU
Earth	1.00 AU
Mars	1.52 AU
Jupiter	5.20 AU
Saturn	9.54 AU
Uranus	19.2 AU
Neptune	30.1 AU

The Light Year

The astronomical unit becomes inadequate when measuring really big distances such as the distance to stars or galaxies outside the Milky Way. The unit for measuring distance changes to light years when these enormous distances are determined. A light year represents the distance travelled by light over a period of one year. To provide some perspective, the Sun is 155 million kilometres from Earth and light travelling from the Sun to Earth will take approximately eight minutes to reach us here. The distance from the Sun to Earth can also be expressed as eight light minutes.

The distance to the nearest star is 16 million million kilometres. The same distance to the nearest star is better expressed as four light years.

How do scientists measure the huge distances between Earth and stars light years away?

One way to measure space distances is to use a method called **triangulation** (a method of determining relative positions of points).

Measuring distances is an important activity. If you are travelling to another city, you want to know the distance so you can calculate your estimated time of arrival. If you know your time of arrival, you can call your aunt so she can have lunch ready for you!

Similarly, we want to know distances in space. Sometimes we can estimate distances. For example, we know planets are closer than stars since planets move against a backdrop of stars that appear stationary.

Measuring Astronomical Distances Indirectly

Distances on Earth are easy to measure. All we have to do is drive in our car and it records the distance on the odometer. In space, distances are more difficult to measure, as we cannot yet take a space vehicle to the nearest star; however, it is possible to measure distances indirectly using a method called **triangulation**.

Triangulation involves using a baseline from which you can measure the angles to an object. By drawing a triangle to scale, you can make an accurate calculation of distance to an object without actually travelling through the distance.

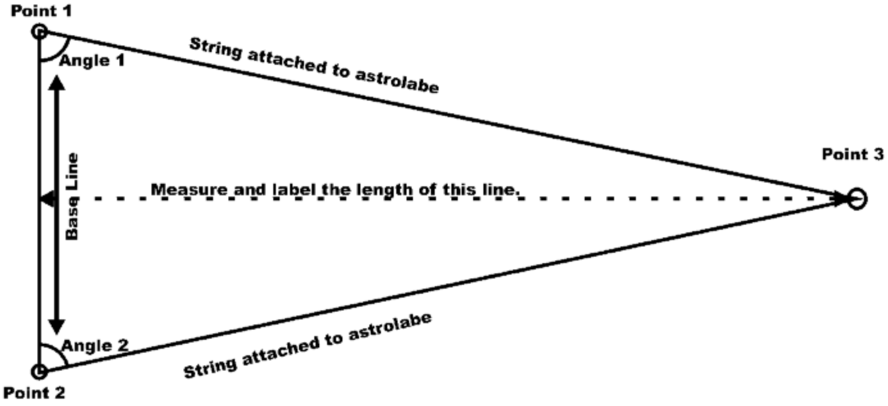
Learning Activity 4.10: Triangulation

Materials:

- astrolabe that you have already constructed
- metre stick
- paper
- small protractor
- centimetre ruler

Procedure:

1. Choose a large room in your house or a classroom. Locate an object at the other end of the classroom (Point 3 on the diagram below). Estimate the distance from where you are at one end of the room to the object at the other end. Record your estimate in the data table that is provided for you on page 104.
2. The diagram below shows how the base line and object to be measured are positioned in a room.
3. Choose a baseline that has two points as shown, that are at least five metres apart. Measure the exact distance between **Points 1 and 2** using a metre stick. Record the base line distance in the data table.



continued

Learning Activity 4.10 (continued)

4. Hold your astrolabe at **Point 1** so that the baseline lines up with the baseline of the triangle. Line the string up with **Point 3** and note the angle the astrolabe is measuring. Record the angle in the data table. If you find it difficult to hold the string and measure at the same time, ask another friend to hold the string for you.
5. Repeat for point 2. Record the angle in the data table.
6. Use the centimetre ruler to draw a triangle **that uses your collected data**. The triangle should look like the one shown in the diagram on the previous page. Use a scale that will give you a baseline that is at least 5 centimetres long. For example, if your baseline is 6.2 metres long, your scale could be 1 centimetre = 1 metre. The line drawn to scale would be 6.2 centimetres long. Record the scale baseline length in the data table.
7. Draw straight lines from Point 1 to Point 3 and from Point 2 to Point 3. You should have a triangle drawn.
8. Draw another line from Point 3 to the baseline so that it meets the baseline at 90°.
9. Measure the length of the line just drawn with your centimetre ruler. Convert the measured length of the line to a distance in metres using your scale. For example, if the distance measured 5.8 centimetres on the diagram, multiply that value by the scale. In this case the scale is 1 m/cm. The actual length of the line would be 5.8 metres.
10. Record the distance from the baseline to the object (point 3) in your data table.

continued

Learning Activity 4.10 (continued)

11. Choose a tree or some other object and measure the distance to it using triangulation. Record your measurements in the data table.

Object		
Estimated Distance		
Baseline Distance		
Baseline Scale Distance		
Angle 1		
Angle 2		
Scale Distance to Object		
Actual Distance to Object		

12. If you wanted to measure the distance to a star, how would you get the huge baseline that would be required?

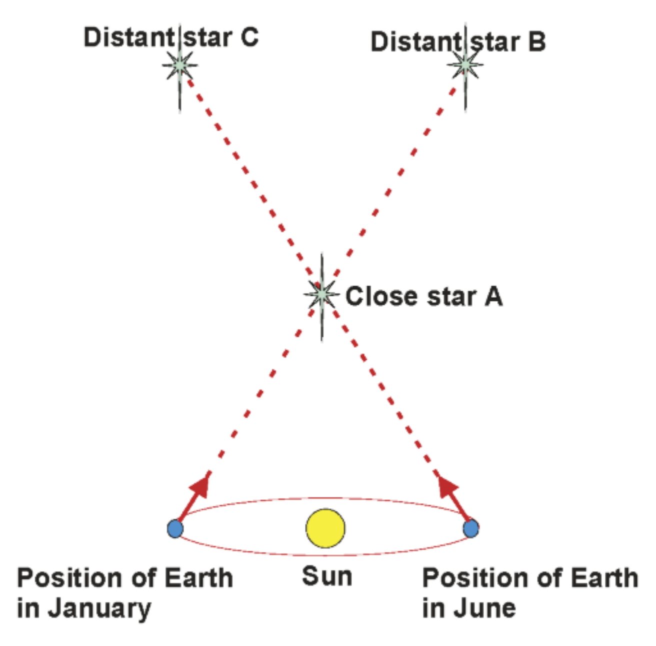
Check the answer key.

Trying to determine the distance to a star using an indirect measurement method such as triangulation is the only way. For the time being, at least, we cannot travel to a star in order to use a space odometer and actually measure the distance.

Triangulation requires a baseline measurement that should be as large as possible. How do we obtain long baselines? What was your answer to question #12 in Learning Activity 4.10: Triangulation?

Using two points located on the circle formed by Earth as it revolves around the Sun would develop a large baseline. You would take one sighting on a star to make the first point on the baseline. Six months later you would take another sighting on the opposite side of the circle. The second sighting would be the second point on the baseline. The diagram below will help illustrate the formation of the larger baseline.

Using the large baselines described above, scientists are able to determine the distance to stars with greater accuracy. Using baselines formed by satellites in space can create even larger baselines.



Diameter of the Earth’s orbit becomes the baseline for measuring star distance using parallax.

Once a long baseline has been established, astronomers look for **parallax** to measure a star’s distance from Earth. In the diagram on the left, a nearby star A is observed twice at two different positions over a period of six months. The two apparent positions of star A are located at positions B and C. Positions B and C are determined by lining A up with two very distant stars that are so far away they appear not to move. The two positions B and C give astronomers the points they need to triangulate the distance from Earth to star A.

Triangulation and parallax, then, are an indirect method of measurement because it does not involve travelling along the distance being measured.

Summary

Because of the incredible distance between objects in space, scientists have developed special units of measurement, including the astronomical unit and the light year. Thanks to the current inability to travel to faraway stars and galaxies, triangulation is required in order to measure astronomical distances. In the next lesson, you will focus on our solar system and the objects within it.

Assignment 4.6: Measuring in Space (10 marks)

You will require the following materials for this assignment:

- small protractor
- centimetre ruler

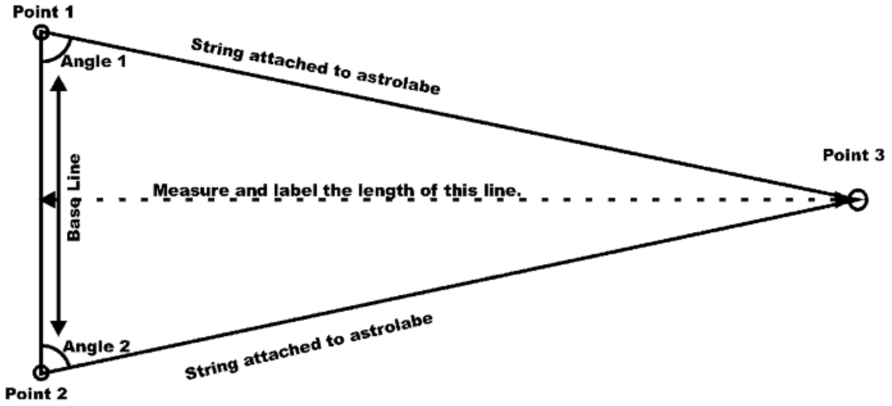
1. What unit of measurement would you use to measure the distance from
   a. Mars to the Sun? *(1 mark)*

      ____

   b. the Sun to the North Star (Polaris)? *(1 mark)*

      ____

2. Use the diagram below to calculate the distance from Point 3 to the baseline. The baseline is 6.2 metres long, Angle 1 is 69 degrees, and Angle 2 is 56 degrees. *(2 marks)*



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continued

Assignment 4.6 (continued)

3. The distance from Earth to the Sun is 1 AU. You want to measure the distance to Pluto. You decide to use the orbit diameter of Earth around the Sun as your baseline. On December 1, the angle your astrolabe made between the baseline and Pluto was 88.5 degrees. On June 1, the angle formed between the baseline and Pluto was 88.5 degrees. Calculate the distance from the Sun to Pluto in AU using triangulation and a scale diagram. Complete your work on a separate piece of paper. *(2 marks)*

4. How long would it take light from the Sun to travel to Pluto in hours, minutes, and seconds? *(2 marks)*

5. A star is located 15.7 light years away from the Sun. How many AU would there be from the star to the Sun? (1 light year = 63 240 AU) *(2 marks)*

LESSON 10: OBJECTS FOUND IN OUR SOLAR SYSTEM

Lesson Focus

After completing this lesson, you will be able to

☐ describe how Earth's moon is positioned to account for the phases of the Moon and lunar or solar eclipses

☐ describe briefly what an asteroid is

☐ describe what a meteor is and what is meant by the term *meteorite*

☐ describe the nature and significance of comets

Key Words

- moon
- gravity
- lunar
- phases
- waxing
- waning
- eclipse
- asteroid
- meteoroid
- meteorite
- meteor
- comet

Online Resources

The following websites provide information on all the solar system objects in addition to meteoroids, asteroids, comets, and moons.

- NASA. High Energy Astrophysics Science Archive Research Center. http://space.about.com/gi/dynamic/offsite.htm?once=true&site=http://starchild.gsfc.nasa.gov
- National Earth Science Teachers Association www.windows2universe.org/our_solar_system/solar_system.html

Moons

Moons are natural satellites that travel around many of the planets in our solar system. Only Mercury and Venus are without such moons. Our moon is our closest neighbour in space. The distance from the Moon to Earth averages about 384 400 km. Because it is so close and beautiful to the eye, yet beyond reach, our moon has been the subject of poetry, superstition, and fascination over the centuries. In any case, we and our only satellite are bound together by that invisible force we call **gravity**.

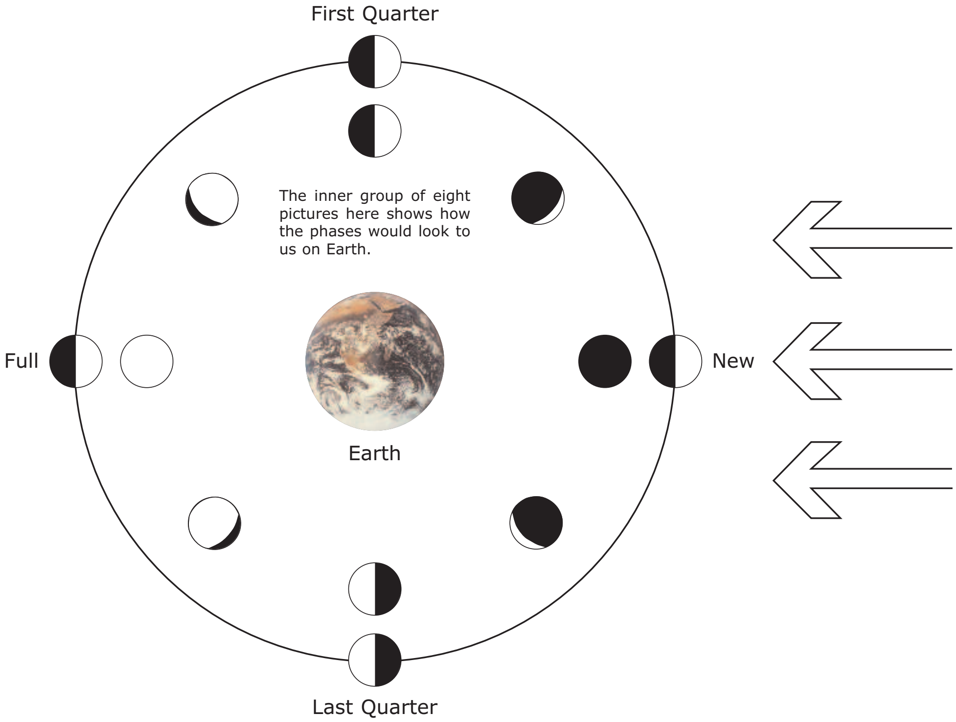
The Roman goddess of the moon was called Luna. From this name we speak about the moon as a "lunar" object. It was once thought people became "lunatics" if they looked too long at a full moon or had an unusual attraction to the Moon.

There was much speculation about the composition of the Moon before the telescope was developed. Once the telescope was developed, the Moon probably became the first object of investigation. It yielded some information and created further questions that have only recently been answered by our spacecraft.

The telescope revealed a moon covered with craters. Where have the craters come from? Further investigation revealed the Moon has only about one percent of Earth's mass. This means the force of gravity created by the Moon is only one-sixth (1/6) that of Earth's. As a result, if any gases and water vapour once surrounded the Moon as an atmosphere—these have long ago escaped to leave an airless, almost waterless satellite. The lack of gases surrounding the Moon means there is no atmosphere to burn up or slow the movement of space objects travelling towards it. As a result, the Moon has been hit with many small and some big space objects, creating a pockmarked surface.

The Moon travels around Earth once every 27 days. The Moon also rotates once on its axis every 27 days. This equal time of revolution and rotation means we see only one side of the moon surface. It was only recently with satellites travelling around the Moon that we were able to see its far side. There really is no "dark side of the Moon." At any one time, half the Moon's surface is illuminated by the Sun. Actually, according to the British art rock band Pink Floyd, "it's all dark."

As the Moon travels around Earth, we see different parts of it lit up based on its position in relation to the Sun and Earth. These different views of the Moon are called **phases**. The cycle of phases occurs again every 29 days as the Moon travels around Earth. The diagram below shows the Moon phases over one revolution of the Moon around Earth.



Notice the full moon takes place when the Moon is on the opposite side of Earth from the Sun. We see the full moon as a bright circle reflecting the Sun's light. The new moon is on the same side of Earth as the Sun. The new moon cannot be seen. As the sunlit portion of the Moon that is visible to us here on the ground gets larger from new moon to full moon, we say it is **waxing**. A few days after new moon, when you see a thin arc-shaped crescent moon in the western sky, we can call that a waxing crescent. As it becomes smaller from full moon to new moon, we say that the Moon's phase is **waning**.

On July 20, 1969, the first human to place a foot on the Moon was American astronaut Neil Armstrong. This remarkable adventure was repeated five more times until the last Moon landing in 1972 with Apollo 17. There were no detectable signs of life on the surface. The Moon, however, has great potential for the future as a possible space station or source of minerals that may be scarce on Earth. Studying our Moon and the Moons of other planets helps us better understand the origin and development of our solar system.

Commander David Scott on the surface of the Moon in 1972—as a member of the crew of Apollo 17—the last mission to reach the lunar surface. The Apollo program was cancelled soon after.*

Eclipses

There are certain times when the position of Earth, the Moon, and the Sun's rays produce spectacular happenings. These exceptional events are known as **eclipses**—a word which means to "cover up" or "move in front of." What we are referring to here are eclipses of the Sun (a solar eclipse) and eclipses of the Moon (lunar eclipses).

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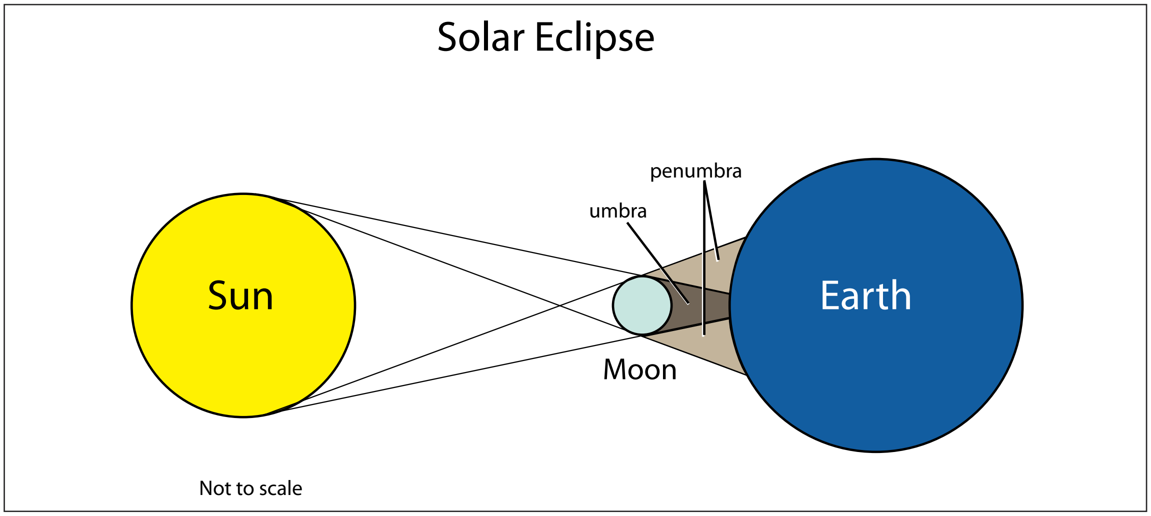
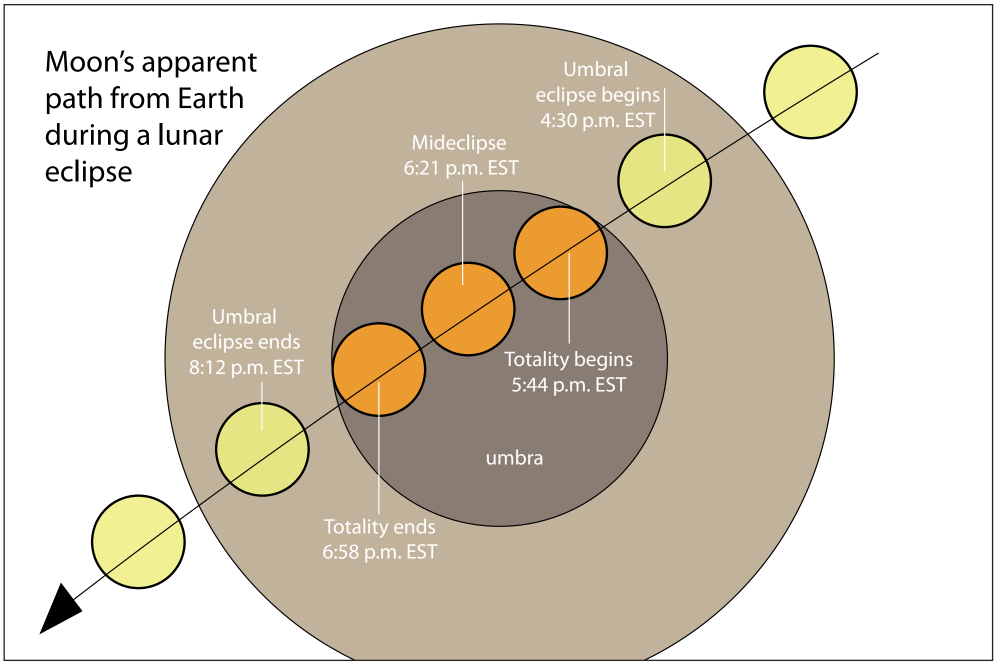
*Photo Credit: Oxford Scientific Films/NASA. Source: Plumb, Donald, et al. *Nelson Science 9*. Scarborough, ON : Nelson-Thomson Learning, 1999. Figure 1. 430. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

A solar eclipse can happen at times when the Moon passes between the Sun and Earth. This can only occur at New Moon phase. If the alignment is near perfect, the shadow of the Moon falls on a narrow strip of Earth's surface, and anyone observing along that thin band of shadow will see the Sun covered up by the Moon for a period of minutes. It is a spectacular event to witness, and many interested people travel to places on Earth just to get the chance to see a total solar eclipse. In 1979 in February, Manitobans were treated to just such an event with Brandon, Manitoba, being one of the best places to be during the eclipse.

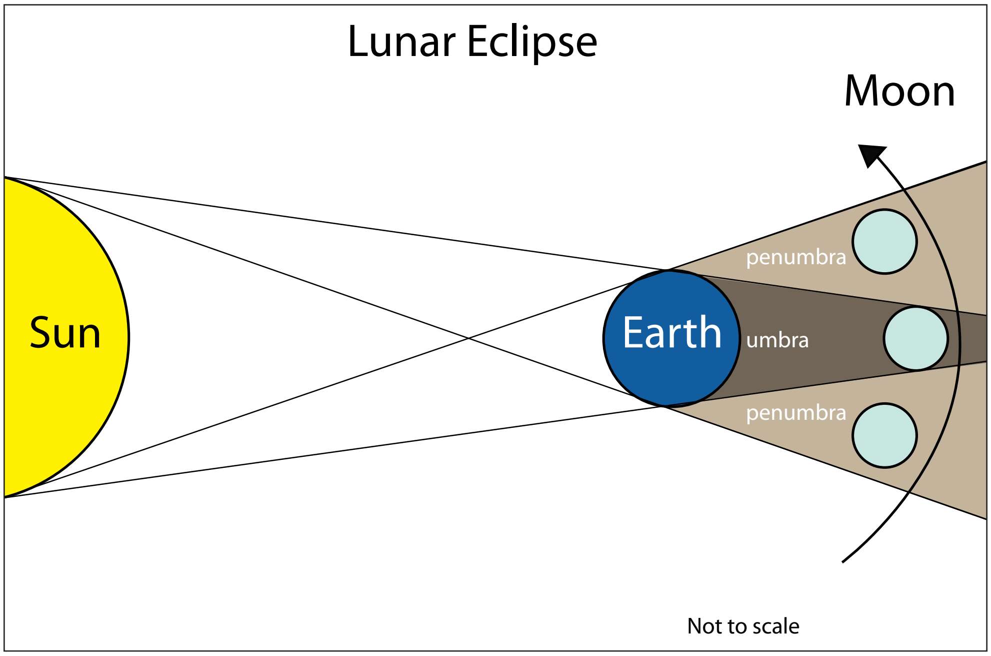
In the diagram that appears here, you can see the path on Earth's surface where observers would see the Sun completely blocked out by the Moon. The reference in the diagram to "umbra" is the scientific name for the Moon's shadow. The word *umbra* literally means "a shadow."



Lunar eclipses happen at times when Earth's shadow does the job. In this case, the Moon passes through Earth's shadow and everyone on one side of our planet can see the show. Lunar eclipses last hours rather than minutes due to the sheer size of Earth's shadow, and we can watch the Moon gradually darken to the point where it almost disappears from view. The diagram below shows the progress of a lunar eclipse over a period of about four hours.

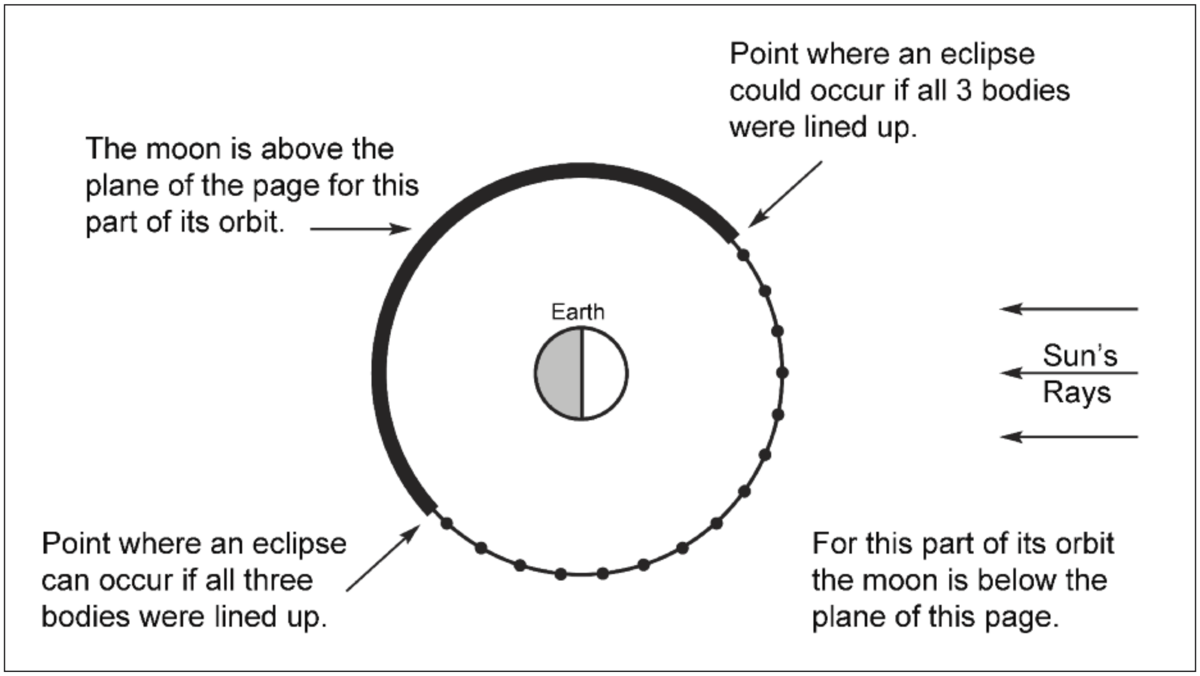


The next diagram shows the positions of Sun, Earth, and Moon at a time when a lunar eclipse can occur. The sizes of the objects are distorted.

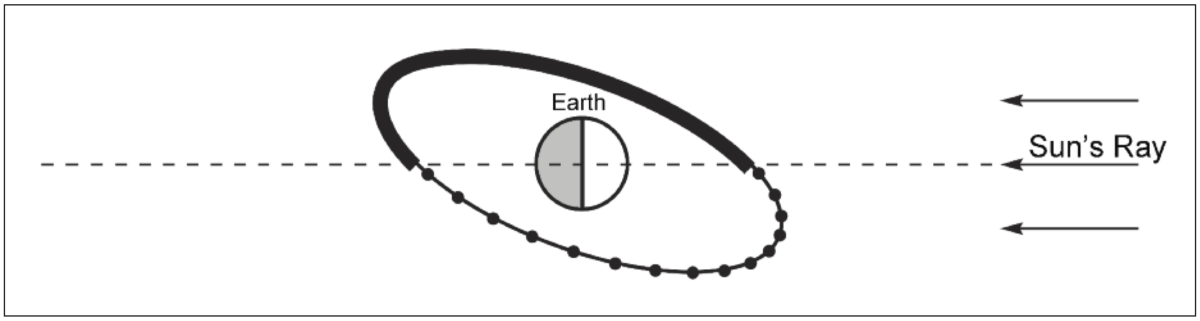


If you were to go back early in this lesson and look at the diagram of the 27-day lunar cycle, it might seem that an eclipse of the Moon will occur once a month. It doesn't happen that way. Why? It's due to the fact that the Moon's orbit around Earth is slightly tilted. Our diagram of the phases of the Moon is on a flat sheet of paper, and so this tilt is not easy to show. Instead, look at the diagram sketched below. Imagine that for part of the Moon's cycle it is below the page, and for the rest of its cycle it is above the page. There are only a couple of places in the Moon's orbit where it would exactly be in a position to block the Sun (at new moon for a solar eclipse) or be in Earth's shadow (at full moon for a lunar eclipse). In most cases, the Moon passes above the Sun or below the Sun at new moon phase, and so a solar eclipse is not possible. Similarly, at Full Moon the moon is either above or below Earth's shadow, and so a lunar eclipse is not possible.

Moon's Orbit: Viewed from Above



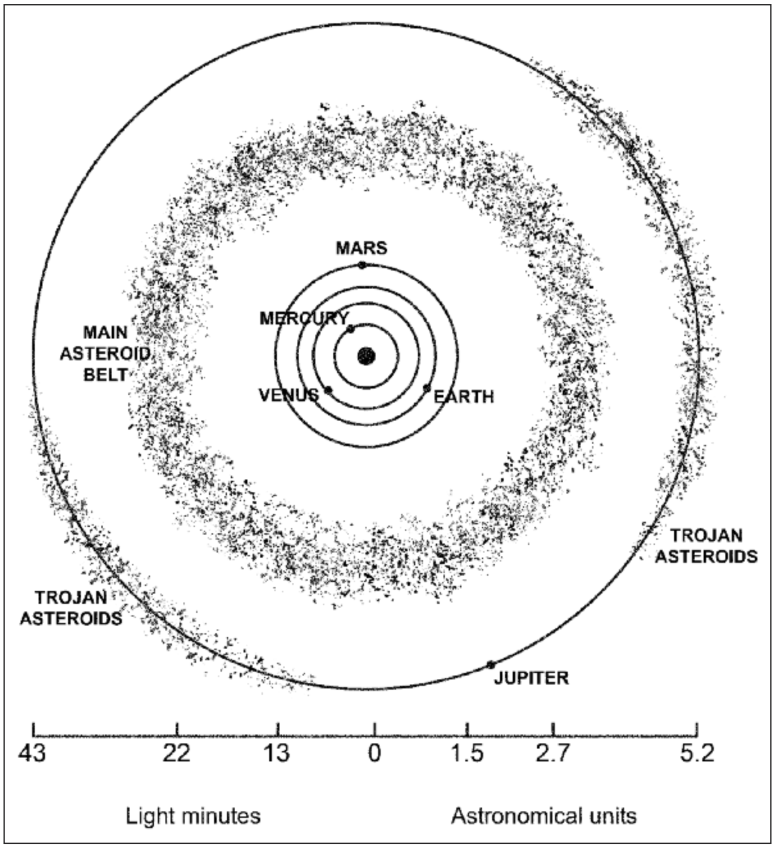
Moon's Orbit: Viewed from Side



Asteroids

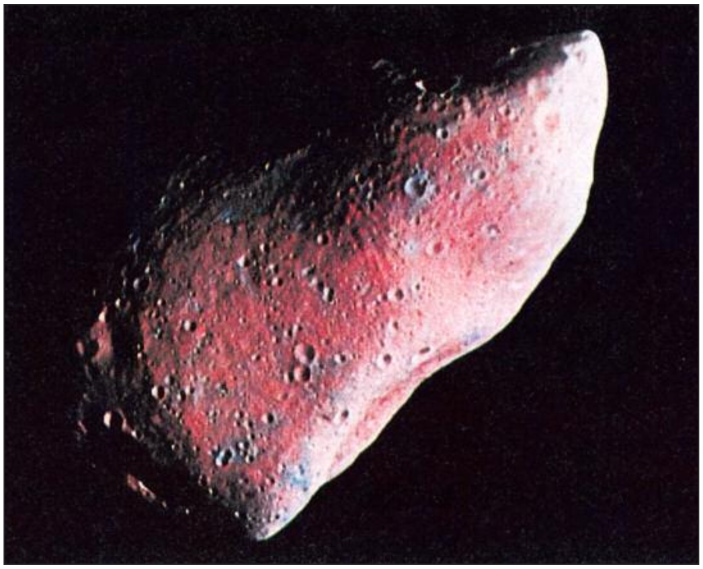
The name **asteroid** comes from the Greek word *astron* which means "like the stars." Asteroids, however, are more like tiny planets as they do not create their own light, but can only reflect sunlight. Asteroids are made of materials similar to our moon.

Asteroids are small planet-like objects, most of which are travelling in heliocentric orbits between Mars and Jupiter. There are hundreds of thousands of small to large (945-kilometre diameter) rock-like fragments forming a broad band called the **asteroid belt**. See the diagram below.



Some asteroids move in elongated orbits that take them through Earth's orbit. These asteroids can come very close to Earth; in fact, asteroids have probably struck Earth at times in its history. Some scientists hypothesize that an asteroid striking Earth about 65 million years ago was responsible for the eventual disappearance of dinosaurs along with many other life forms.

Asteroids can collide with each other and with other much smaller space objects. Collisions result in irregular surfaces on asteroids that are pock marked like the surface of the Moon. Smaller asteroids are often irregularly shaped because they do not have a mass large enough to create the gravitational force to mold them into a sphere.



The asteroid Gaspra*

Meteors and Meteorites

A **meteoroid** is a lump of rock-metal that is trapped by the Earth's gravitational field and is pulled into the Earth's atmosphere. A meteoroid can be any space object including an asteroid.

Once the meteoroid enters the Earth's atmosphere it begins to heat up due to friction caused by the Earth's atmosphere. As the air and meteoroid get hotter, they give off a bright light and the meteoroid begins to burn up.

If the meteoroid burns up completely before hitting Earth, it is called a **meteor**, but if the meteoroid survives the journey, strikes the Earth, and pieces of it can be collected, these space rocks are called **meteorites**.

Meteor showers are common several times a year as Earth travels through, what most scientists think is, debris from a comet. These showers are often called "falling stars," but they are not made of stars; they are small pieces of comet moving into our atmosphere and burning up from heat caused by air friction. Meteor showers are best observed between midnight and morning. The best showers are the Perseid shower (mid-August), the Leonid shower (peaking around November 17), the Geminid shower (December 14), and the Quadrantid shower (January 3–4). These would be good dates to observe some celestial fireworks.

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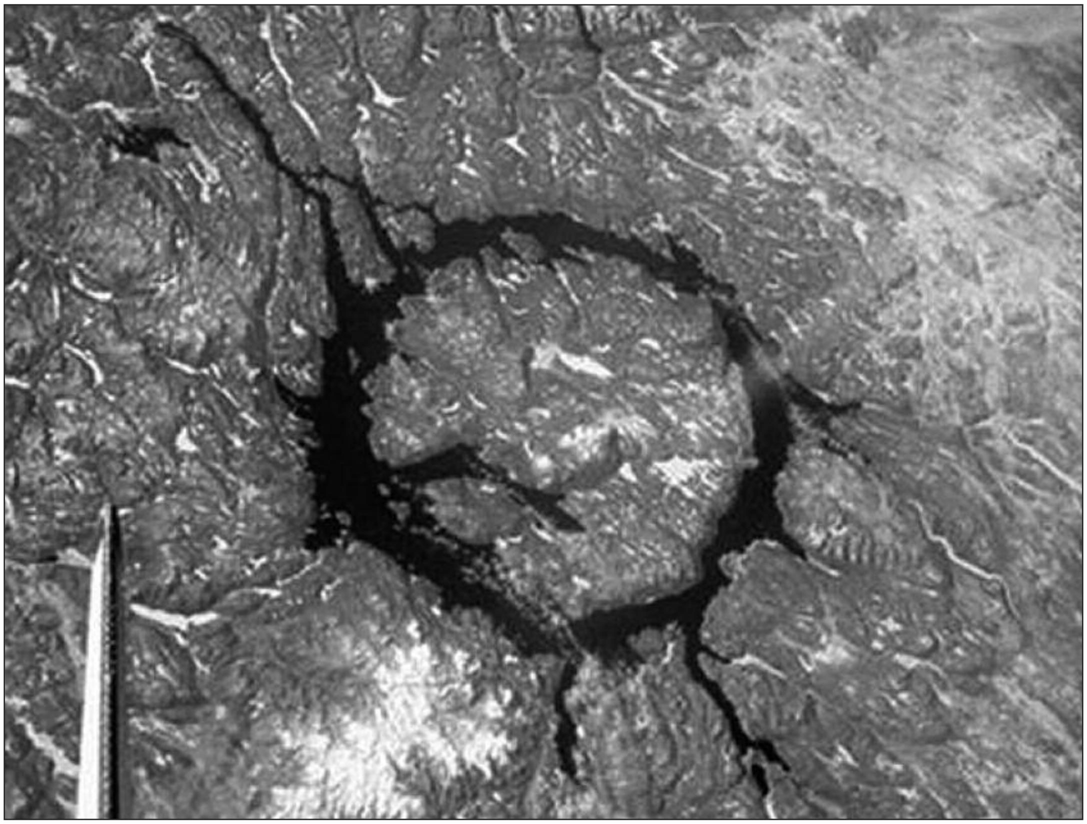
*Photo Credit: JPL/TSADO/Tom Stack & Assoc. Source: National Geographic, Ralph M. Feather Jr., and Dinah Zike. *Glencoe Science: Astronomy*. Columbus, OH: Glencoe/McGraw-Hill, 2005. Figure 22. 93. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

Meteorites, of course, are the survivors of the trip through the Earth's atmosphere. The Earth gains approximately a quarter ton of mass (250 kilograms) each day from meteorites colliding with Earth.

There have been some huge craters carved into the Earth's surface by meteorites. Canada's surface is home to a few of the more spectacular examples of preserved meteor craters such as the Manicouagan crater in northern Quebec (see image below). Manitoba's own West Hawk Lake is also thought to be the remnants of a meteor strike that occurred thousands of years ago. Yet another crater was gouged into Earth's surface by a train-car sized meteorite that moved 400 million tons of rock to form Meteor Crater in Arizona.



Manicouagan Reservoir crater in northern Quebec as photographed from NASA's space shuttle (see the tail of the shuttle in the image?); this crater is over 200 km across.*

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*Image Credit: NASA. Source: NASA. "Manicouagan Reservoir." *Solar System Exploration: Multimedia: Gallery*. 2011. http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=792. Reproduced with permission.

Meteorite Crater in the Arizona desert (after a bit of overnight snow)*

Image of the West Hawk Lake impact crater site**

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*Photo Credit: Georg Gerster/Photo Researchers. Source: National Geographic, Ralph M. Feather Jr., and Dinah Zike. *Glencoe Science: Astronomy*. Columbus, OH: Glencoe/McGraw-Hill, 2005. Figure 20. 92. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

**Source: NASA. "Section 18: Basic Science II: Impact Cratering." *Remote Sensing Tutorial*. http://rst.gsfc.nasa.gov/Sect18/Sect18_4.html. Reproduced with permission.

Comets

From earliest times, comets have been mysterious to human observers. “Where did they come from?”, “What were they made of?”, and “Why did they seem to have a tail?” were common questions. For centuries people believed comets were a signal of a coming disaster or war. The very word *disaster* means “a bad star.” Halley’s comet appeared just before the Norman invasion of Britain in the year 1066 CE. When the English King Harold was told of the comet’s appearance, he nearly fell off his throne from fear—or so the story goes.

Gradually, as observers kept track of the comets appearing in the sky, they observed that the same comet would appear again after a period of years went by. This repeatability allowed them to predict the next appearance of certain comets. These return visitors are known as “periodic comets.” There were other comets, however, that made a single appearance in the sky, and were then never seen again. It all depends on a comet’s orbit.

Comets are made of two parts: the head (or coma) and the tail. The coma is made of a nucleus that is the densest part and can be up to several kilometres in diameter. The rest of the coma is made of a gas and can have a diameter up to hundreds of thousands of kilometres.

The tail of the comet is made of fine particles of dust and gas. The tail can also be millions of kilometres long. As the comet travels close to and around the Sun, the tail points away from the Sun. Here’s why. Surface materials from the comet are driven off by the stream of charged particles that comes from the Sun, called the “solar wind.” This gives the familiar “tail” of the comet. Because the solar wind always moves outward from the Sun, the comet’s tail must always point away from the Sun. The tail glows brightly as a comet approaches the Sun. The solar radiation from the Sun warms the comet and melts the ice in the coma. The melted materials form a vapour that begins to shine brightly as it absorbs energy from the Sun. As the comet finishes its trip around the Sun and moves away, its tail disappears and it is no longer visible until its next trip back.

Learning Activity 4.11: Objects in Space

1. What other name is given to a moon that travels around a planet?
2. Compare the time of rotation of the Moon to its time of revolution.
3. What determines the phases of the Moon?
4. What Roman goddess' name gave our moon its name?
5. Most asteroids are located between which two planets?
6. What name is given to the band of asteroids?
7. What name is given to a space object once it enters Earth's gravity?
8. What name is given to the objects that burn up in Earth's atmosphere?
9. What are two parts of a comet?
10. Research and describe what might happen if a giant meteorite struck Earth. Choose a place where the meteorite hits land.
11. What evidence do we have that space objects have hit the Moon?
12. An asteroid is heading toward Earth. You have two years before collision. What would you recommend as actions to save Earth or its inhabitants?

Check the answer key.

Summary

In addition to the planets, there are objects that inhabit our solar system, some permanently and some only occasionally. Moons and most asteroids are permanent. Comets and some asteroids are more occasional visitors.

Larger planets have more moons than smaller planets. Our moon has no atmosphere. You would be able to make great leaps on the Moon as a result of its smaller force of gravity compared to that on Earth.

Asteroids are planet-like objects, most of them occupying a band of space called the asteroid belt. The asteroid belt is located between Mars and Jupiter (see the graphic earlier in this lesson as a refresher).

Meteoroids can be asteroids, comet debris, or some other space object that comes under the influence of Earth’s gravity field. Meteoroids that move into Earth’s atmosphere and burn up are called meteors. Meteoroids that travel through Earth’s atmosphere and hit Earth are called meteorites.

Comets have a history of superstition associated with them. Gradually, as more information was gathered, they became known as natural occurrences that repeated themselves periodically. Comets have a coma and a tail. The tail is the most spectacular part of the comet as it points away from the Sun and can be millions of kilometres long.

Learning Activity 4.12: Self-Quiz 2

You can use this learning activity (together with Learning Activity 4.9 and Learning Activity 4.14) to test your knowledge of concepts within this module.

Multiple Choice

1. You are located on the ocean and need to determine your longitude. You could use a
   a. sextant
   b. chronometer
   c. cross-staff
   d. either (a) or (c)
2. Cosmology refers to
   a. a study of the beginnings of the universe
   b. a study of shapes formed by stars
   c. an attempt to form a description of one's future by studying the stars
   d. the art and science of applying makeup
3. If you were located on the North Pole and determined the altitude of Polaris, you would have a reading of
   a. 0°
   b. 45°
   c. 90°
   d. 180°
4. Light travels from the Sun to Earth.
   a. The time it takes is called a light year.
   b. The time it takes would be one day.
   c. The distance is called an astronomical unit.
   d. The distance would be a little more than the distance to the Moon.

continued

Learning Activity 4.12 (continued)

Matching

5. Match the letter of the best choice in the right column with the space provided in the left column.

_____ Polaris

_____ constellations

_____ latitude

_____ Milky Way

_____ retrograde motion

_____ parallax

_____ light year

a. North Star
b. apparent backward motion of a planet
c. a measure of the angle between equator and North/South Pole
d. used as an indirect method to measure distance of stars
e. distance light travels in one year
f. the galaxy that we occupy
g. used by ancient cultures for help in navigation

Short Answer

6. A navigator measures the North Star and measures its altitude at 28 degrees and its azimuth at 43 degrees. The latitude of the navigator is ____________________.

7. Why is the accurate measuring of the seasons important?

8. If Earth’s axis doesn’t wobble back and forth, how is it possible for Earth to be inclined toward the Sun in the summer and away from the Sun in the winter in the Northern Hemisphere? Diagrams would be helpful in answering this question.

9. What unit of measure would you use when measuring the distance from our neighbouring galaxy, Andromeda, to us? ____________________

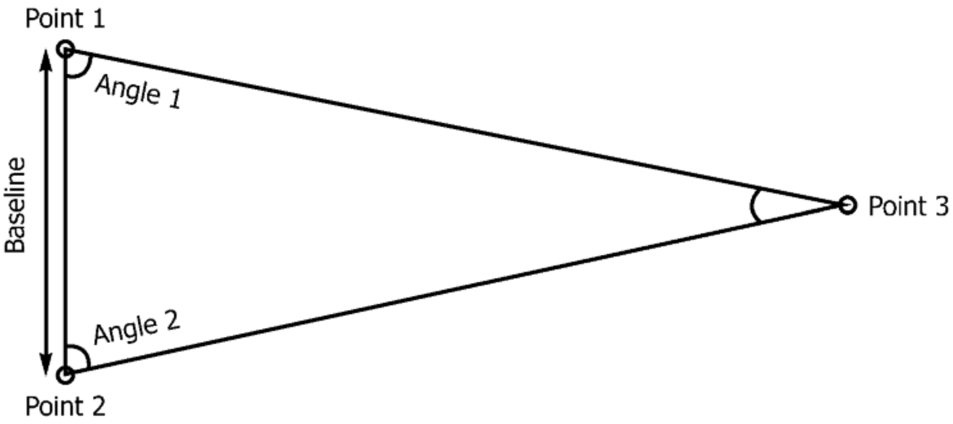
10. How is it possible to get a large base for measuring the distance to a star by triangulation?

continued

Learning Activity 4.12 (continued)

Problem

11. Use the diagram below to answer the questions.



The distance to a close star was measured using triangulation. Point 1 and Point 2 are Earth positions one-half year apart.

Angle 1 = 27°

Angle 2°

a. What is the length of the baseline if the distance from Earth to Sun is 163 000 000 kilometres? ______________________

b. What is the distance from Earth to the star? Use a scale diagram.

Check the answer key.

Notes

LESSON 11: NEBULAE, STARS, AND GALAXIES

Lesson Focus

After completing this lesson, you will be able to

- ☐ explain the following terms: *luminosity*, *stars*, *binary stars*, *galaxies*, *nebulae*, *red giant*, *red dwarf*, *supernova*, *neutron star*, *pulsar*, *black holes*, and *quasars*
- ☐ label a diagram of the Sun
- ☐ explain the fusion process
- ☐ explain the terms *apparent* and *absolute magnitude of brightness*
- ☐ explain how black line spectrum can determine the composition of stars
- ☐ describe the contributions made by Herschel and Hubble to understanding stars
- ☐ state the different shapes of galaxies

Key Words

- fusion
- luminosity
- apparent magnitude
- absolute magnitude
- spectroscope
- electromagnetic spectrum
- binary star
- solar mass
- nebula
- red dwarf
- red giant
- white dwarf
- supernova
- neutron star
- pulsar
- red supergiant
- black hole
- open cluster
- globular cluster
- quasar

Online Resources

The following websites provide information about stars.

- NASA. High Energy Astrophysics Science Archive Research Center.
  http://space.about.com/gi/dynamic/offsite.htm?once=true&site=http://starchild.gsfc.nasa.gov

  Click on "Universe" under Level 2.
- National Earth Science Teachers Association
  www.windows2universe.org/the_universe/the_universe.html
- About.com
  http://space.about.com/gi/dynamic/offsite.htm?once=true&site=http://antwrp.gsfc.nasa.gov/apod/astropix.html

  This site provides space images—there is a new image posted every day.

Introduction

Stars are the common element of the universe. There are approximately 400 billion stars in our galaxy, the Milky Way. It is thought there are approximately 100 billion galaxies in the universe. In order to get some idea about what 400 billion means, we can bear in mind the number of people born since Earth began has probably been less than the number of stars in the Milky Way.

Our Closest Star–The Sun

Online Resource

The following website provides information about the Sun.

- NASA. High Energy Astrophysics Science Archive Research Center.
  http://space.about.com/gi/dynamic/offsite.htm?once=true&site=http://starchild.gsfc.nasa.gov

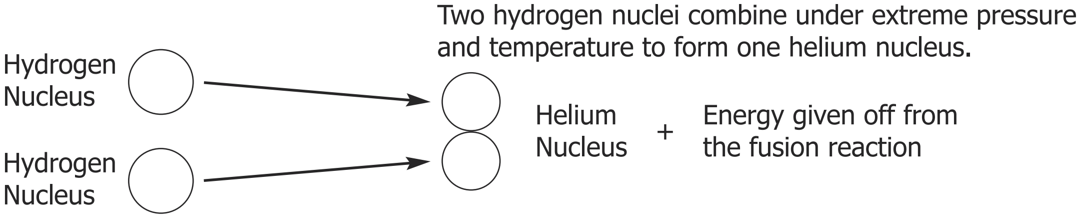
  Click on “Solar System” under Level 2.

Our closest star, the Sun, is the brightest object in space. The Sun provides almost all our energy and food on Earth. The Sun provides light energy for photosynthesis to take place in plants. Plants are the basic food for all animals.

As you consider all the sources of energy that you use—from hydroelectric to gasoline—the Sun was responsible for their production. The Sun’s importance to us is obvious; for this reason we will take a closer look.

We say the Sun is burning, but it is not burning in the ordinary sense of the word, as a campfire burns. The burning of the Sun is really a nuclear **fusion** process. Nuclear fusion is the process of taking hydrogen nuclei and fusing or joining them together to form a larger helium nucleus. Each time this reaction takes place there is some heat and light given off. When there are a huge number of fusion reactions taking place, there are equally huge amounts of energy and light given off. Nuclear fusion takes place on our Sun and the same reaction takes place on every star.

Nuclear Fusion Reaction



Both hydrogen and helium are gases. All stars are made of these two gases. Hydrogen and helium on Earth are both less dense than air, but in a star the gases are compressed to such an extent by gravity that they become very dense. All stars are giant balls of mainly hydrogen and helium gas.

Our Sun is about halfway through its life cycle. Right now, the Sun is composed of 25 percent helium and 75 percent hydrogen. Scientists expect that the Sun will remain as it is for another 5 billion years when it will run out of hydrogen fuel. Other stars are at different stages of their lives. Some are dying now, some will continue producing light and energy for many billions of years beyond the Sun's lifespan.

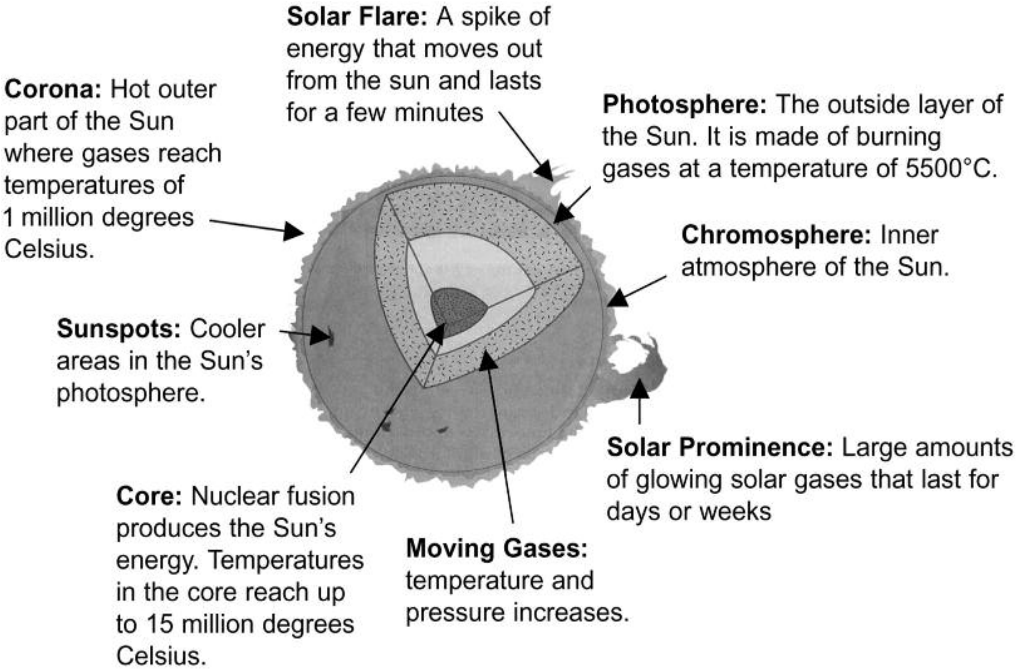


Diagram of the Sun

Luminosity

The Greek astronomer Hipparchus was the first to begin classifying stars according to their brightness. He classified star brightness into six categories where first magnitude stars would be the brightest and sixth magnitude stars the faintest. While his method of classification has been modified slightly in modern times, the same system is still used today.

Scientists now use two types of classification for star brightness.

- **Apparent Magnitude**

  Apparent magnitude refers to the brightness of a star as it appears to us. We know from practical experience that car lights appear less bright at a greater distance. The apparent brightness of stars works the same way. When two stars have the same brightness, the one farther away appears less bright. This difference in brightness is called apparent magnitude.
- **Absolute Magnitude**

  Absolute magnitude refers to the brightness of a star regardless of its location. We can use car lights to illustrate absolute magnitude by realizing that the two sets of lights really have the same brightness even though they seem different. We would say the two sets of car lights have the same absolute magnitude brightness since they both give off the same actual amount of light energy.

Once scientists were able to determine the distance to stars, they could factor in distance and determine the absolute magnitude of star brightness. Another word we can use for brightness is *luminosity*. Luminosity of stars tells us something about their composition. Luminosity refers to the total amount of energy a star gives off per second. Some stars can give off 30 000 times as much light energy as the Sun and some stars give off 10 000 times less light energy than the Sun.

While the Sun’s apparent magnitude of brightness is the greatest, its absolute magnitude of brightness places it in the average range for stars.

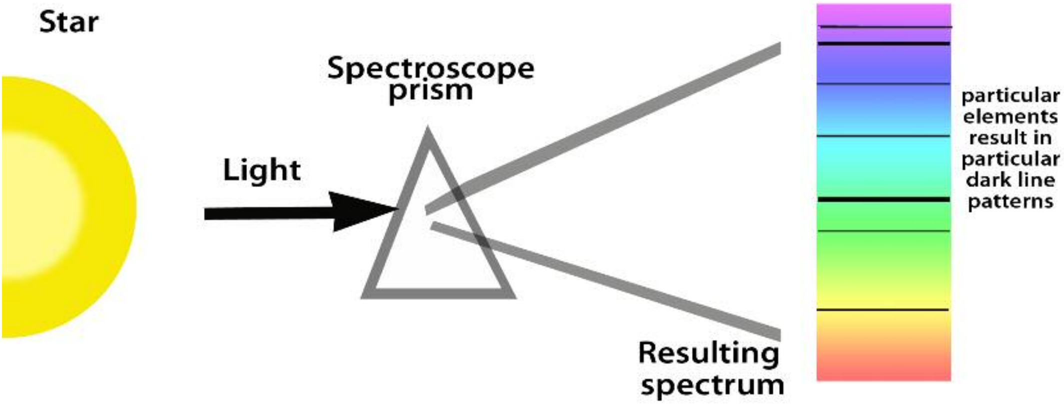
The Temperature and Colour of Stars

Stars all seem the same when we look at them in the sky. In fact, there are many different colours of stars, ranging from blue through red. The colour of a star tells scientists something about its surface temperature. A yellow star like the Sun would have a hotter surface than a red star, while a blue star would be the hottest.

The Spectroscope—"Starlight and Rainbows"

A **spectroscope** is a tool scientists use to break white light into its spectral colours. You have probably seen sunlight, which is white light, travel through a prism or even a piece of ordinary glass and form the colours that we often call the rainbow colours. The spectral colours also appear in a rainbow as the sun shines through raindrops and produce the range of colours from red through violet. A prism shown in the diagram below is breaking sunlight apart and projecting the spectral colours onto a screen.

The image below shows how a **spectroscope** works with starlight to determine what gases make up that star's outer layers.



A star is the hot incandescent light source. The cooled gases surrounding the star are located between the star and the spectroscope. The light from the star travels to Earth, through the spectroscope, and is projected on a screen. The spectral colours from red through violet and some black lines can be observed on the screen of the diagram on the left.

The black lines in the spectrum show the elements that make up the gas surrounding the star. White light produced in the core of the star passes through the corona where the gases have cooled down. The gases in the corona absorb wavelengths that are characteristic of each gas. If hydrogen is one of the gases, then black lines would show up in the spectrum in places characteristic for hydrogen. Helium and any other gas would also have a pattern of black lines identifying them. In this way scientists are able to learn something about the composition, temperature, and direction and speed of travel of stars.

The Size and Mass of Stars

Once scientists know the luminosity of stars, they are able to determine their mass and size. They discovered that stars range in size from one tenth the radius of the Sun to 1000 times the Sun's radius.

The mass of stars was impossible to determine until scientists realized that over half the stars exist as **binary stars**. A binary star is made of two stars travelling around each other. Once the size of the orbit and the time it took to travel around the orbit was known, the masses of both stars could be calculated. The mass of stars is measured in **solar mass**, where a solar mass of one is equal to the mass of the Sun.

The Life of a Star

The life of a star refers to the stages it passes through from the beginning to the end of its existence. The life of a star takes place over billions of years.

All stars begin their life in **nebulae**. A nebula is a cloud of gases and dust that swirl around in space. As the dust and gases swirl, they begin accumulating in larger clumps. As the clumps become larger the force of gravity becomes a large force, pushing the accumulated mass closer and closer together. Eventually, if the process continues, the mass becomes large enough to produce the pressure required for a fusion reaction to start. Once the fusion reaction is initiated, a star is born.

There are many beautiful nebulae in space. There are photographs on the Internet that will give you some idea of their beauty. The nebulae are named according to their shapes. For example the Horsehead Nebula has a shape that suggests the head of a horse. (See the picture below taken by a Manitoba astronomer while vacationing in the Arizona desert.)

Horsehead Nebula*

Online Resource

The following website provides information about different types of stars.

- National Earth Science Teachers Association
  www.windows2universe.org/the_universe/the_universe.html
  Click on "Stars."

Scientists have categorized stars according to their mass and temperature.

- **Small Stars**

  Small stars have the least mass. They form a star called a **red dwarf** that has a fusion reaction for approximately 10 to 100 billion years. Interestingly, a smaller size star reacts for a longer time. Toward the end of the star's life it has used up its supply of hydrogen and swells up to form a large cool **red giant**. The outer layers of gas move away and the core shrinks to form a **white dwarf** star. The white dwarf gradually becomes a faint light.

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*Courtesy of Kevin Black, Winnipeg, Manitoba. Used with permission.

- **Medium-sized Stars**

  A medium star forms quickly from a nebula to produce a hot dense star. Nuclear fusion lasts for a few million years producing light 5000 times as bright as our Sun. After fusion ends, the core collapses and the star explodes, producing a **supernova**. A supernova produces a large cloud of gas or nebula and a smaller core. The core becomes a **neutron star** and the nebula will produce another star when conditions are right.

  A neutron star is an extremely dense star made of neutrons. These stars are so dense a handful of star material would have a mass of millions of kilograms.

  One type of neutron star is a **pulsar**. A pulsar produces very high-energy radio waves. These stars are quite small—about 20 kilometres in diameter—but very dense. Pulsars rotate rapidly resulting in regular pulses of radio wave energy that scientists at first thought were messages from outer space.

- **Large Stars**

  In a relatively short time, the star is formed and gives off extremely large amounts of energy because of its immense size. Nuclear fusion in big stars lasts for only one million years or so. After the hydrogen is used up, the star swells in size to form a **red supergiant**. If the star is massive enough, its core may collapse and its outer layers can be blown off in a fantastic explosion that we call a **supernova**. The supernova blasts material outward into space, and the material can then form a large nebula that has the potential to form other new stars. The core material collapses on itself to form a **black hole**.

  A star 30 times larger than our Sun is massive enough to form a black hole when it dies. A black hole is extremely dense and nothing, including light, can escape its force of gravity.

Online Resources

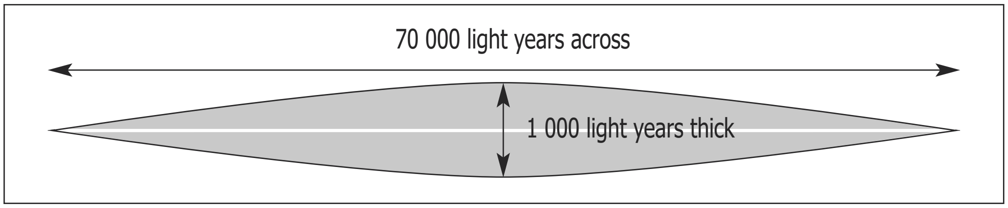
The following website provides information about black holes and other deep-space objects.

- About.com
  http://space.about.com/od/starsplanetsgalaxies/u/StarsPlanetsGalaxiesPath.htm#s4

Galaxies and Star Clusters

Our galaxy, the Milky Way, is disk shaped with a bulge in the middle. There are about 200 to 400 billion stars collected together to form the disk. The disk is about 70 000 light years from edge-to-edge and about 1000 light years thick. The Milky Way galaxy rotates around the central bulge.

A star cluster is a group of stars, between 10 and 1 million, too few to be called a galaxy. **Open clusters** have between 10 and about 1000 stars and are located along the main band of the Milky Way. **Globular clusters** consist of 100 000 to 1 million stars and are located outside the Milky Way.



In the late 1700s William Herschel stated that some fuzzy patches of light, which looked like nebulae, might be galaxies. In 1924 Edwin Hubble, using the 255-centimetre Mount Wilson telescope, showed that what was considered the Andromeda nebula was actually a spiral galaxy far away from our own. The Andromeda is now known to be 2 million light years away from us.

As scientists explored space with better telescopes, they discovered many galaxies. The number of galaxies is so large, in fact, that they are described as countless, but a safe estimate indicates there are billions of galaxies.

Galaxies take different shapes. Hubble identified three shapes of galaxies—irregulars, spirals, and elliptical or egg shaped. Hubble refined this classification scheme further but for our study you need to know only the three basic shapes.

There are some objects in space that are not yet understood. One such object is a **quasar**. A quasar is an extremely distant object in space that appears to be only a small dot, yet it produces 100 times the energy of our whole galaxy. Maarten Schmidt at Mount Palomar discovered the first quasar in 1963.

Summary

Stars are fascinating. We have observed them since the beginning of time but when it comes to understanding them, we have barely scratched the surface. Stars seem to be constant in every aspect. We now know, however, that stars are constantly changing. Their change is imperceptibly slow taking place over periods of time, making our life span seem very small.

Assignment 4.7: Stars (20 marks)

1. Name our closest star. *(1 mark)*

2. Describe what happens in a fusion reaction. *(2 marks)*

3. What is the difference between a solar prominence and a solar flare? *(1 mark)*

4. When is the Sun’s energy produced? *(1 mark)*

5. What part of the Sun is seen when there is a total eclipse? *(1 mark)*

continued

Assignment 4.7 (continued)

6. Use two flashlights to illustrate the meaning of relative and absolute brightness. *(2 marks)*

7. How can a black line spectrum reveal information about the composition of a star? *(2 marks)*

continued

Assignment 4.7 (continued)

8. What is a nebula? *(1 mark)*

9. How does a nebula form a star? *(2 marks)*

continued

Assignment 4.7 (continued)

10. Name the products when a small, medium, and large star each run out of hydrogen. *(3 marks)*

11. Name the three basic types of galaxies. *(3 marks)*

12. What is the difference between a star cluster and a galaxy? *(1 mark)*

LESSON 12: SPACE TECHNOLOGIES

Lesson Focus

After completing this lesson, you will be able to

☐ explain the difference between aircraft and spacecraft flight
☐ explain how spacecraft go into orbit or space travel
☐ describe two types of satellite orbits
☐ describe how satellites are used for remote sensing and telecommunications
☐ describe what is taking place in staffed space activities
☐ describe what is taking place with space probes
☐ describe problems with Earth telescopes
☐ describe the development and problem solving that accompanied the Hubble Space Telescope

Keywords

- thrust
- escape velocity
- geosynchronous
- low Earth orbit satellite
- high Earth orbit satellite
- Global Positioning System
- space shuttle
- International Space Station
- space probe
- light pollution
- ozone layer

Online Resources

The following website provides information about the NASA space shuttle program.

- About.com
  http://space.about.com/od/spaceshuttlemissions/Space_Shuttle_Missions.htm

The following website provides information about the history of the International Space Station.

- NASA
  www.nasa.gov/mission_pages/station/structure/iss_assembly.html

The following website provides information about technologies developed in Canada.

- Canadian Space Agency
  www.asc-csa.gc.ca/eng/satellites/default.asp

Introduction

Space technology has been responsible for major advancements in space science. The list of technological advancements is very long. Technology became increasingly more sophisticated in the twentieth century—astronauts actually walked on the Moon. You are now experiencing early twenty-first century technology—what great events are going to take place as a result of your generation's advances?

The astrolabe was the first tool mentioned in this module—it enhanced the ability of mariners to cross oceans and come back again. The astrolabe eventually evolved into the sextant, a more precise and easily used navigational tool.

The most dramatic technological development for astronomy—until the twentieth century—was the telescope. Galileo Galilei immediately realized the potential of the telescope, made one, and pointed it to the sky above. Galileo was able to see what no one had seen before. The telescope advanced and developed into different forms. First, the refracting telescope was modified to become a reflecting telescope. Visible light telescopes were modified to detect and record the presence of radio waves, infrared waves, and high-energy radiation such as X-rays and gamma rays. These advancements to the telescope allowed a more complete understanding of stars.

Space travel, both with people onboard and using robotic spacecraft, has made use of many advancements in technology. We take for granted now events such as space shuttle take offs and landings, pictures of Saturn and its rings and moons, and rock samples from the Moon.

Some areas of interest in the space sciences are outlined briefly below.

Flight Technology

Humankind has for many centuries looked at birds and wanted to fly. At the beginning of the twentieth century, flight as we know it today began to take shape. Two requirements for flight included

- some way of providing thrust either through a propeller or a jet engine
- some way to lift the aircraft through a fixed wing on an airplane or a moving wing on a helicopter

Regardless of how flight takes place, air is required. Air is needed to provide oxygen for combustion in the engine or turbine and air is needed to provide lift on the wing surface in order that the aircraft fly.

Most aircraft remain within 15 kilometres (15 000 metres) of Earth's surface where the atmosphere is most dense. The atmosphere surrounding Earth extends to a maximum distance of approximately 150 kilometres. The space shuttle normally orbits at about 450 kilometres above the surface, well above the atmosphere as we know it.

A spacecraft must have a rocket attached to give it the **thrust** needed to send it into space. A rocket does not fly in the ordinary sense of the word. There are no wings to provide lift. A rocket is designed to travel in a trajectory much like a bullet. The rocket thrust will be over before leaving Earth's atmosphere but by that time the rocket has reached **escape velocity**. Escape velocity is the speed a rocket needs to achieve in order to leave the gravity of Earth or any object in space. Interestingly, the escape velocity is the same for all rockets regardless of their size for a given planet. For Earth, a rocket must reach a velocity of about 11 kilometres per second in order to achieve orbit. The stronger the gravity field, the higher the escape velocity will be. For instance, launching from Jupiter occurs where the escape velocity is greater than 60 kilometres per second, and for Mars, only about 5 kilometres per second.

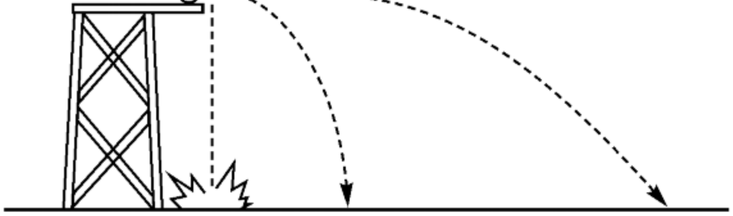
Rockets do not require oxygen in the atmosphere to burn as they carry their own oxygen supply. Rockets are entirely self-contained, furnishing all their own chemicals needed for providing thrust.

Once the rocket leaves Earth's atmosphere, its trajectory is established and its path is set. The small rockets attached to the spacecraft provide any minor changes in the direction of the spacecraft. Since there is no atmosphere and therefore no oxygen in space, the spacecraft must carry its own oxygen supply for the small rockets to function.

The trajectory of a spacecraft can either take it into Earth's orbit or into space where the Moon or other planets act as slingshots to redirect the spacecraft and speed it up in its journey.

As the spacecraft orbits Earth, the force of gravity provides the force necessary to keep the spacecraft in orbit. There are different speeds at which spacecraft orbit Earth. Some orbits involve a spacecraft speed that takes only about 90 minutes to complete an orbit. Some orbits occur at a speed (and distance from Earth) that keeps the satellite above the same spot on Earth all the time; such an orbit is called **geosynchronous**, meaning "keeping time with Earth." Its the distance from Earth's surface that determines the speed that a satellite must maintain. Communications and television broadcast satellites orbit at a distance of about 46 000 kilometres from Earth.

Did You Know that having spacecraft in orbit is a fundamental aspect of space travel? Escape velocity is important to consider when planning to put something in orbit. The idea of putting things in orbit goes back as far as Newton and can best be understood by arguments he put forward. Imagine dropping a cannonball by rolling it off a tower. It would strike the ground immediately below it. If you gave some horizontal velocity, by pushing it, it would fall a short distance from the tower. With more velocity, it would fall further from the tower. The illustration below shows the trajectory of the cannonball for increasing velocities.



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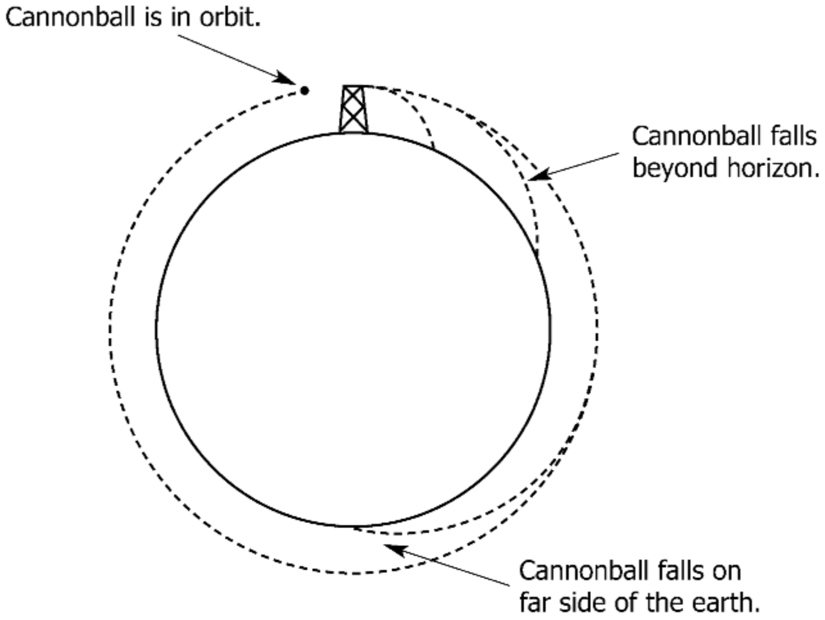
(continued)

But let us consider Earth, which is spherical and which allows much greater speeds for the cannonball. We must also neglect air resistance for this point. With enough velocity the cannonball could be made to fall beyond the horizon and with even more velocity it could fall on the other side of Earth. And with even still more velocity it could be made to travel "horizontally." That is, it would still be falling towards Earth (under the pull of gravity) but the cannonball would be covering so much distance "horizontally" that Earth would be "curving" or "falling away" as fast as the cannonball was dropping. It would then be keeping the same distance above ground. It would be in a very low orbit. In reality, we must account for the frictional drag of the atmosphere so satellites are put in orbits above the atmosphere. But they are still "falling towards" Earth under the pull of gravity. They don't fall down to the ground because their horizontal velocity moves them along so that they trace a closed loop around Earth the same way our cannonball made its low altitude loop around Earth. And our example of the perfectly circular orbit is just the simplest case. Orbiting satellites make use of this principle even when their orbits are not circular.



Earth orbit satellites exist as two types:

- **Low Earth Orbit Satellites**

  In 1963, Canada sent its first satellite, *Alouette 1*, into space. *Alouette 1* was considered a low Earth orbit satellite since it had an altitude between 200 and 1000 kilometres. These satellites travelling at speeds of 28 000 kilometres per hour will orbit the Earth in about 90 minutes. These fast moving satellites are used for remote sensing. A remote-sensing satellite makes images of Earth using ordinary light digital cameras. These satellites also use infrared light, radio waves, and high frequency waves to form images. Different forms of electromagnetic radiation provide scientists with different kinds of images. For example, infrared light gives scientists images that show healthy vegetation as a red colour. Radio waves and microwaves are used by the Canadian satellite system RADARSAT to map Earth's surface. The advantage of radio waves and microwaves is that they can travel through clouds. Remote sensing is particularly useful in helping weather forecasters predict weather.

- **High Earth Orbit Satellites**

  Telecommunications ("tele" means far) has become increasingly important in the second half of the twentieth century. Low Earth orbit satellites need very high speeds to balance the force of gravity acting on the satellites that are small distances away from Earth. The high speeds mean the tracking systems needed to receive signals from the satellite would be very complex and expensive. High Earth orbit satellites can travel much more slowly since the force of gravity at much larger distances is greatly reduced. If a satellite is located above the equator at an altitude of 36 000 kilometres above Earth and travels at 11 060 kilometres per hour, the satellite will be in geosynchronous orbit. For us on Earth, the satellite would appear stationary, but the satellite is really travelling around the centre of Earth once every 24 hours. Geosynchronous orbits make satellite tracking unnecessary. Satellite dishes need to be set once and then left alone.

Canada has become a leader in telecommunications. Our first geosynchronous orbit satellite was *Anik 1* sent up in 1972. Since the first *Anik*, other more advanced telecommunications satellites have been placed in orbit.

There are 24 satellites placed in 12-hour orbits at a distance of 20 000 kilometres above Earth's surface. These satellites are not in geosynchronous orbit but form a **Global Positioning System (GPS)** that is used for navigation. This system has the advantage of being able to send as well as receive signals to and from the satellites.

Staffed Space Activities

The first artificial satellite in space was the Sputnik, launched in 1957. The first staffed spacecraft was sent up by the Soviet Union in 1961. Yuri Gagarin was the cosmonaut who piloted the spacecraft. The Americans and the Soviets improved their rockets over the years until large payloads were sent into space. Astronauts and cosmonauts were able to spend increasing amounts of time in space and eventually land on the moon.

Up to this point spacecraft had to be discarded after each journey. The Americans overcame this problem by developing the **space shuttle**, which was large enough to allow huge payloads and could be reused for further space flights.

Another example of staffed spacecraft is the space station. The first space station was built by the Soviet Union and was named *Salyut 1* and was placed in orbit in 1971. Since that time the Soviet Union used the space station *Mir*.

The current and most spectacular space station is called the **International Space Station** (ISS). The International Space Station is a cooperative venture of the United States, Europe, Canada, Russia, and Japan. The space shuttle will take materials and astronauts back and forth between Earth and the ISS.

The following links provide plenty of resources on the space shuttle and the space station. The information is extensive and stays current right up to the week.

Online Resource

The following website provides information about the International Space Station, including Canadian contributions to its missions.

- Canadian Space Agency
  www.asc-csa.gc.ca/eng/iss/default.asp

Space Probes

Space probes are much less expensive than staffed spacecraft to use; they also can travel distances we would never attempt with staffed spacecraft since we do not need to get them back to Earth. Much of what we know about the planets in our solar system has been determined by space probes.

Online Resources

The following websites provide information about past, current, and future space missions.

- NASA
  www.nasa.gov/missions/past/index.html
- NASA
  www.nasa.gov/missions/current/index.html
- NASA
  www.nasa.gov/missions/future/index.html
- Calvin J. Hamilton
  http://solarviews.com/eng/homepage.htm

The Hubble Space Telescope

Since Galileo, scientists have been able to study space with telescopes, but always from Earth's surface. Some disadvantages of looking through the atmosphere include the following:

- **Light pollution** is becoming more of a problem as cities, towns, and even farmyards become filled with unused and sometimes unnecessary light. Unused light generally is light that travels upward and reflects off clouds to form a light haze around cities and towns. Light pollution makes it difficult for astronomers to see dim light produced by stellar objects. Light pollution also has unpleasant and even dangerous effects when it shines in the eyes of motorists and birds causing disorientation.

Online Resource

The following website provides information about light pollution and programs that seek to reduce its effects.

- CBC
  www.cbc.ca/news/background/space/light-pollution.html

- The atmosphere absorbs some wavelengths of light. Fortunately for us, much of the harmful short wavelength radiation (UV rays) from the Sun is absorbed in the **ozone layer**. Much of the more harmful portion of the Sun's electromagnetic radiation is removed, making it possible for life, as we know it, to exist. For astronomers, however, the removal of any part of the electromagnetic spectrum makes it more difficult for them to analyze the structure, motion, and history of a star.
- The atmosphere distorts light by scattering some wavelengths and bending the light rays. The atmosphere also reduces the intensity of light as it travels to the surface of Earth.

  As a result, the atmosphere reduces clarity of the image produced by telescopes and also reduces the distance through which a telescope can see a star.

In an attempt to reduce the effect of the atmosphere, telescopes have been placed on mountaintops where the atmosphere is thinner. The image below is of the Canada-France-Hawaii telescope sitting on top of Hawaii's tallest volcano.

The Hubble Space Telescope solves all the problems described above. In 1973 NASA selected a team with the objective of designing a space telescope. The telescope was constructed at the end of 1985. The Hubble Space Telescope was then launched into space with the large payload capability of the space shuttle. The Hubble Space Telescope was launched into space on April 24, 1990.

The first images observed were fuzzy. There was great disappointment as it was discovered the lenses were not correctly ground to the right specs. On December 2, 1993, a crew on the space shuttle *Endeavor* installed corrective lenses and the images were brought into clear focus. Hubble Space Telescope has two cameras, two spectrographs, and some guidance sensors to help aim the telescope. Astronauts on a further trip in 1997 added more instruments and repaired the insulation surrounding the telescope. You can see how important it is for astronauts to visit the telescope in order to do repairs and how valuable the space shuttle is for this purpose. In the spring of 2009, the very last repair mission was accomplished, giving the space telescope its best set of "eyes" ever. By 2015, the work of this remarkable instrument will have come to an end after nearly 20 years—its orbit will be allowed to decay and it will burn up in Earth's atmosphere.

The images sent to us by the Hubble Space Telescope are images that contain light that began its journey to us from some stars as long ago as 8 billion years. How many light years would it be to that star? The Hubble Space Telescope allows us to "time travel" and go back to observe what was taking place when the universe was much younger.

Online Resource

The following website provides images and information about the Hubble space telescope.

- Astronomy for Kids Online
  www.astronomy-for-kids-online.com/hubbletelescope.html

Learning Activity 4.13: Technology in Space

1. Why is air necessary for aircraft flight?
2. Spacecraft flight doesn't need air. Explain this statement.
3. Why do rockets need escape velocity to travel into space?
4. Why is it difficult to use communication satellites with low Earth orbit satellites?
5. Explain the Canadian connection to the RADARSAT satellite.
6. What are telecommunications?
7. What is a geosynchronous orbit?
8. Why is a geosynchronous orbit satellite good for communications?
9. What is GPS used for?
10. What is the International Space Station?
11. Why are space probes often used instead of staffed spacecraft?
12. Name two probes used to explore Mars.
13. Name three problems with telescopes that must look through Earth's atmosphere?
14. When was the Hubble Space Telescope launched?
15. What was wrong with the Hubble Space Telescope initially and how was it repaired?

Check the answer key.

Summary

With satellites, spacecraft, space stations, and telescopes, humans have developed a wide array of technology to assist in our study of the universe beyond Earth. The next lesson will introduce you to the specific contributions that Canadians have made toward space exploration.

LESSON 13: CANADA'S INVOLVEMENT IN SPACE

Lesson Focus

After completing this lesson, you will be able to

☐ demonstrate an understanding of the contribution Canada has made to space science

☐ briefly describe two international projects where Canada is cooperating with other nations

Key Words

- *Alouette*
- International Satellites for Ionospheric Studies
- Canadian Space Agency
- Sudbury Neutrino Observatory
- Solar Tower Atmospheric Cherenkov Effect Experiment
- ODIN
- Gemini
- Canada-France-Hawaii Telescope
- Canada-France Redshift Survey
- Liquid Mirror Technology
- Canadarm
- MOST
- International Space Station
- Next Generation Space Telescope
- *Anik*

Online Resources

The following websites provide information about Canada's involvement in space and space flight.

- Virtual Museum of Canada
  www.virtualmuseum.ca/Exhibitions/Cosmos/english/resources.html
- Canadian Space Agency
  www.asc-csa.gc.ca/eng/default.asp

Introduction

Canada has a long history of space research beginning in 1839 when the University of Toronto constructed a magnetic observatory. In the twentieth century, Canada specialized in upper atmosphere research. By the 1930s, Canada was a leader in studying the northern lights.

By 1957, Canada was studying the atmosphere and ionosphere, and the aurora borealis and its effect on communications. Scientists used a suborbital rocket released from a site at Churchill, Manitoba.

During the 1960s Canada sent up a research satellite, ***Alouette* 1**. *Alouette 1* represented Canada's entry into the space age. With the *Alouette*, Canada became the first nation beyond the Soviet Union and the USA to launch an artificial satellite. *Alouette* was designed to monitor the upper ionosphere and was the first of many cooperative ventures between Canada and the USA. *Alouette* was designed to stay in orbit for one year but it worked so well that it was left up for 10 years and sent back over one million pictures of the ionosphere.

A second joint venture with the USA required three satellites for ionosphere research. The *Alouette II* and a pair of more complex satellites called *ISIS I* and *ISIS II* were employed for this purpose. The ISIS satellites were an acronym for **International Satellites for Ionospheric Studies**. The two ISIS satellites were able to send back considerably more data than the Alouette satellites.

The Viking satellite was sent up by Sweden in 1986, but Canada had provided an instrument called an Ultraviolet Imager (UI) as part of the payload. This operation demonstrated a pattern that was to signal Canada's method of participation in international space programs. Canada had developed several areas in which there was a high level of expertise and technology.

In 1989 the Canadian space program operations were transferred to the newly created **Canadian Space Agency**.

The space science program developed by the Canadian Space Agency has as its duty to “promote the peaceful use and development of space, to advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits to Canadians” (Canadian Space Agency).

Currently the Canadian space science program is based on international cooperation. Canada builds scientific instruments to fly on a variety of platforms and international satellites. This is how Canada can be involved in space programs that are too complicated and expensive for us alone.

Astronauts’ Achievements

Canada has had astronauts on the space shuttle since 1984 when Dr. Marc Garneau spent eight days conducting experiments on a shuttle mission.

In 1992, Dr. Roberta Bondar conducted a series of experiments on the space shuttle discovery.

Also in 1992, Dr. Steve Maclean flew on space shuttle Columbia and conducted space science experiments.

In 1996, Dr. Bob Thirsk performed a Torso-Rotation Experiment.

In 1998, Dr. Dave Williams flew on NASA NeuroLab shuttle mission with Canadian life sciences research. Dr. Williams is director of NASA’s Space and Life Sciences program.

Chris Hadfield was involved with the shuttle/*Mir* cooperative venture in 1995 that provided an opportunity for astronauts to live and work with Soviet cosmonauts. There were seven such missions between 1995 and 1998 as part of a cooperative venture for phase 1 of the International Space Station.

Online Resource

The following website provides information about Canadian astronauts.

- Canadian Space Agency
  www.asc-csa.gc.ca/eng/astronauts/default.asp

Research

Space is a great laboratory for many types of experiments. Canada has been involved in space research from the beginning.

The Alouette and ISIS satellites have allowed Canada to be leaders in ionosphere research. Experiments at Churchill have placed Canada at the forefront in northern lights research.

The study of human health in space helps keep space travellers from suffering negative effects of space travel. There are also some benefits coming from space research for those of us who remain on Earth.

Some problems coming from space travel include the following:

- Space sickness

  The balance organ found in our inner ear becomes mixed up in space where there is no apparent gravity. Space travellers become dizzy, nauseous, and will even vomit as a result.
- Muscles grow smaller and bones lose calcium. The lack of apparent gravity in orbit means that muscles are not being used much of the time; as result, muscles become smaller and bones lose their calcium and become brittle.
- Imbalance of body fluids

  The lack of apparent gravity means body fluids rise up into the upper body causing the heart to swell. In addition, the changed fluid balance in the body can affect the function of kidneys.
- Cosmic radiation

  Astronauts will experience more cosmic radiation on a single trip in space than they will in several years on Earth. Astronauts are checked regularly to determine what long-term effects, if any, will occur as a result of their exposure to cosmic radiation.
- The **Sudbury Neutrino Observatory** (SNO) is located in a mine in Sudbury approximately 2000 metres below surface. This is one of three such observatories around the world and is considered the best as it makes use of heavy water from Atomic Energy of Canada. Scientists will attempt to detect the most elusive of all particles—the neutrino.
- The **Solar Tower Atmospheric Cherenkov Effect Experiment** (STACEE) is a joint experiment with the USA to explore a certain wavelength of electromagnetic radiation not yet detected with any instrument. The results of this experiment will help scientists better understand such objects as pulsars.

- The **ODIN** satellite project led by Sweden also involves Canada. This project studies the ozone layer and makes use of equipment developed in Canada.
- The **Gemini** project is a cooperative venture with Argentina, Brazil, and the USA to place two specialized infrared telescopes in Hawaii and Chile.
- The **Canada-France-Hawaii Telescope** (CFHT) was built in 1979 and offers one of the best observing points in the world—atop Hawaii's tallest volcano.
- The **Canada-France Redshift Survey** (CFRS) tries to answer one question: "What would the universe around us have looked like if we had lived when it was only half its present age?" Canadian and French researchers are collecting data from distant galaxies. The galaxies are far enough away to produce a red shift that indicates they are looking at light that is one-half a universe old.
- **Liquid Mirror Technology** is a technique by which liquids (mercury) are whirled in a circle and form a lens. The technique would offer lenses that are much less expensive and much larger. The concept was first proposed by Newton and is being researched in two Canadian universities.
- The **Canadarm** was first launched aboard STS-2, the second shuttle flight on November 12, 1981. The Canadarm is a major contribution by Canada to international space exploration. The Canadarm has been used on high-profile tasks many times since it was first placed in the space shuttles. One notable example occurred when the space shuttle was sent up to perform repairs on the Hubble Space Telescope. The Canadarm was used to retrieve the Hubble Space Telescope, and replace it in orbit after the repairs were performed.
- The **MOST** project provides Canada with an opportunity to explore the universe using an extremely small telescope in orbit 800 kilometres above the Earth's surface. The satellite will weigh only 50 kilograms. The telescope will represent huge reductions in cost as well as weight and will send back information that will help determine the composition and age of stars.
- The **International Space Station** is a joint effort among nations including Canada to position a large space station in orbit to provide a place for scientific research. Canada participated in the Gravitational Biology Facility (GBF) by providing the Insect Habitat (IH), which was a 10-year research project. There were 12 insect containers, six of which were kept at zero-g or "weightless" and six kept on a centrifuge to provide a one-g (the force of gravity that we experience on Earth) environment in space. A number of experiments were performed on the insects.

Scientists are already planning a new space telescope. The cooperative effort is called the **Next Generation Space Telescope** (NGST). The NGST was launched in 2009 and will have an expected life span of 5 to 10 years. The telescope will have significant advances over the Hubble Space Telescope (HST).

- The mirror will have a diameter of eight metres, about 10 times larger than the HST.
- The NGST will have one quarter the mass of the HST.
- The NGST will be in orbit 1.5 million kilometres from the surface of the Earth, four times farther away than the moon is.

  The NGST will be using infrared wavelengths of light to determine how our universe began.

Space Scientists

Clarence Augustus Chant

Chant is called the “father of Canadian astronomy” because he trained so many Canadian astronomers in his role as professor of astrophysics at the University of Toronto.

Terence Dickinson

Dickinson has written many books about astronomy and has been editor of several astronomy magazines.

Mary Lou Whitehorne

Whitehorne received the Chant Medal in recognition of her contribution to Canadian astronomy as one of Canada’s most active amateur astronomers.

This brief list was placed in the lesson to show representatives of Canadian astronomy from the scientist to the amateur. Each person can be considered a space scientist as they look through a telescope and answer questions about the universe in which we live.

Online Resource

The following website provides information about Canadian astronomers.

- Canada. Canada’s Digital Collections. http://epe.lacbac.gc.ca/100/205/301/ic/cdc/universe/canadian.html

Communications

Canada has become a telecommunications leader world-wide with ***Anik*** series of telecommunications satellites. *Anik* means “little brother” in Inuit. *Anik A1* was launched in 1972 as one of the first domestic communications satellites in geosynchronous orbit. The eleventh *Anik* satellite, *Anik F1*, is ready to be sent into space at this time.

Summary

Canada has a long history of space science research and development. Canadians have created niches where their experience and knowledge make them able partners in the search for understanding about the universe.

Notes

LESSON 14: THE IMPACT OF SPACE SCIENCE AND TECHNOLOGIES ON HUMANS AND THE ENVIRONMENT

Lesson Focus

After completing this lesson, you will be able to

- ☐ describe how nations working together are able to
  - ☐ search for intelligent life in other solar systems in the galaxy
  - ☐ work to detect and protect Earth from collisions with space objects
  - ☐ consider long-term space travel and develop colonies in space
  - ☐ use remote sensing to improve understanding of Earth environments

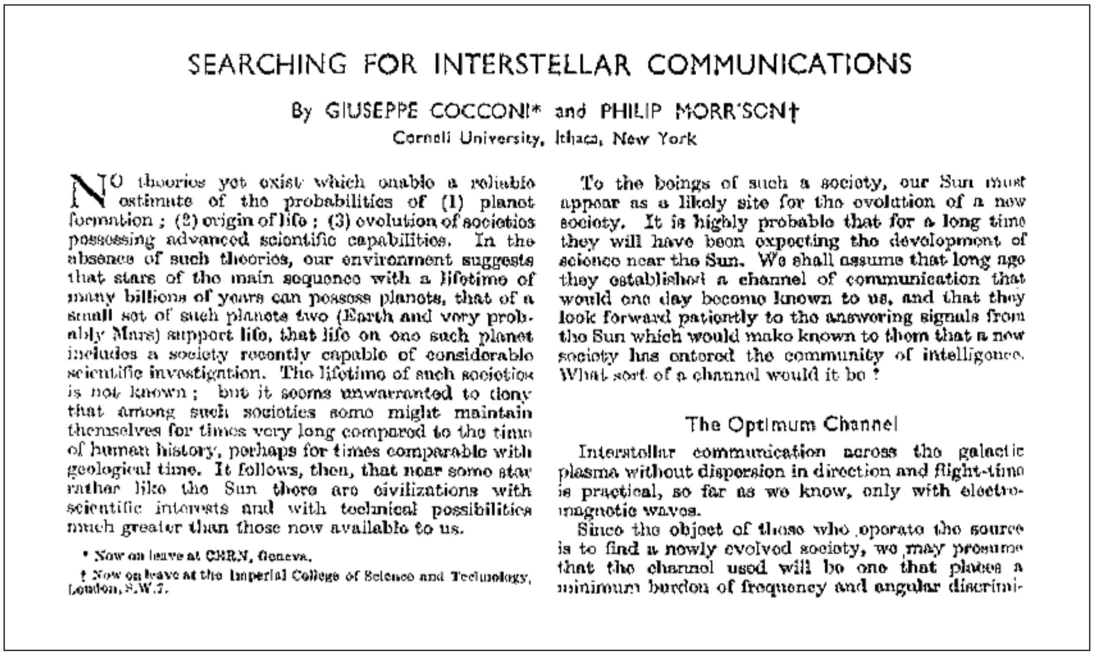
Extraterrestrial Life and Habitat

The possibility of communicating with life beyond Earth has intrigued many individuals. Questions such as, “Does life exist elsewhere in the galaxy?”, “Would they be both intelligent and friendly?”, and “What might they look like?” have been asked by each of us at one time or another.

The Search for Extraterrestrial Intelligence (SETI) began at the scientific level in 1961 when Frank Drake organized a meeting with a group of scientists and began exploring the possibility of detecting life in the universe.

A couple of years prior to the meeting, two physicists—Giuseppe Cocconi and Philip Morrison—had written an article in the British science journal *Nature* (published in 1959 under the title “Searching for Interstellar Communications”) stating that radio telescopes had become sensitive enough to detect transmissions sent out by extraterrestrial life from planets orbiting other stars.

Here is the first page of the article written in 1959 by Cocconi and Morrison.*



SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI* and PHILIP MORRISON†
Cornell University, Ithaca, New York

NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation; (2) origin of life; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for times comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence. What sort of a channel would it be?

The Optimum Channel

Interstellar communication across the galactic plasma without dispersion in direction and flight-time is practical, so far as we know, only with electromagnetic waves.

Since the object of those who operate the source is to find a newly evolved society, we may presume that the channel used will be one that places a minimum burden of frequency and angular discrimi-

* Now on leave at CERN, Geneva.

† Now on leave at the Imperial College of Science and Technology, London, S.W.7.

When you look at the introduction to their article, you can see that these two scientists struggled with the lack of a theory to help explain the following:

- Why do planets form around certain stars?
- How does life originate on a planet, and how common is this?
- How do societies develop advanced scientific and technological capabilities?
- How long would such societies last? Would they develop communications that could travel beyond their own planet?
- Is it possible that intelligent, communicating societies eventually destroy themselves?

They suggested a radio signal would be logically sent out with a wavelength of 21 centimetres, the wavelength of the chemical element hydrogen. In 1960, Drake used a 25-metre dish to begin a systematic study of radio waves at the 21-centimetre wavelength. By the time of the meeting he had not been able to detect any signal which would indicate an intelligent civilization. As Drake prepared for the meeting, he developed what is known as the Drake Equation. The equation was a first attempt at using a mathematical approach for determining the possibility of life anywhere in the universe. There are

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*Source: Cocconi, Guiseppe, and Philip Morrison. “Searching for Interstellar Communications.” *Nature* 184 (1959): 844–846. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff.*

seven different items that go into this calculation, and the result gives the number of planets in our galaxy that could support (or have supported) intelligent, communicating civilizations. Here's what it looks like:

$$N = N^* f_p n_e f_l f_i f_c f_L$$

The equation can really be looked at as a number of questions:

N^* represents the number of stars in the Milky Way Galaxy.

Question: How many stars are in the Milky Way Galaxy?

Answer: See if you can find this out.

f_p is the fraction of stars that have planets around them.

Question: What percentage of stars have planetary systems?

Answer: Make an estimate.

n_e is the number of planets per star that are capable of sustaining life.

Question: For each star that does have a planetary system, how many planets are capable of sustaining life?

Answer: What might this answer be for our solar system?

f_l is the fraction of planets in **n_e** where life evolves.

Question: On what percentage of the planets that are capable of sustaining life does life actually evolve?

Answer: This estimate can be anywhere from 0 percent (life never evolves) to 100 percent (life always evolves).

f_i is the fraction of **f_l** where intelligent life evolves.

Question: On the planets where life does evolve, what percentage evolves intelligent life?

Answer: Estimates range from 100 percent down to near 0 percent.

f_c is the fraction of **f_i** that communicate.

Question: What percentage of intelligent societies have the scientific means and then go on to communicate?

Answer: Take a guess.

f_L is fraction of the planet's life span during which the communicating civilizations live.

Question: For each civilization that does communicate, for what fraction of the planet's life does the civilization survive?

Answer: This is a very tough one to estimate. Earth, for example, has been in existence for about 4 600 000 000 years. As far as we know, humanity has had the ability to send out radio communications for about 100 years and no more than that. One-hundred years—when compared to over 4 BILLION years—is not a long time. Also, it is difficult to determine how long we will be communicating using electromagnetic waves.

When all of these variables are multiplied together we come up with **N**, the **number of intelligent, communicating civilizations in the galaxy**.

Online Resource

The following website provides a calculator for the Drake Equation.

- PBS
  www.pbs.org/lifebeyondearth/listening/drake.html

The SETI Institute is dedicated to determining whether intelligent life exists outside Earth. So far, the work of the SETI Institute has not detected any indication that intelligent, communicating life exists anywhere in space.

Online Resource

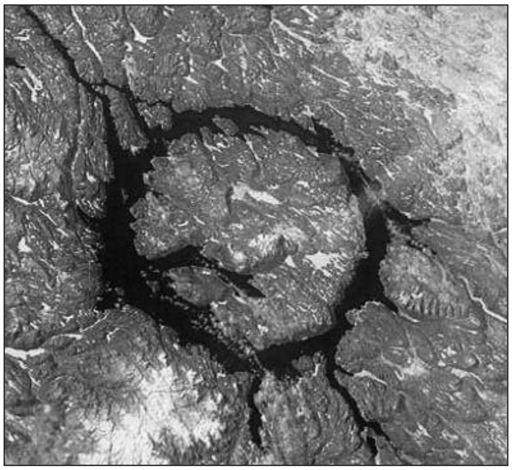
The following website provides information about the SETI Institute.

- SETI Institute
  www.seti.org/

Prediction of Potentially Catastrophic Impacts

Impact craters are formed when a large meteoroid, asteroid, or comet smashes into a planet or satellite. Every object in our solar system has received impacts: Earth has received its share of impacts, but weathering and the effect of vegetation have greatly reduced visible evidence.

About 120 Earth impact craters have been located. Two craters are shown in the images on the following page.



The Manicougan impact crater was formed in northern Quebec. This is the largest impact crater in Canada. The crater diameter is about 200 kilometres.*

The Barringer meteor crater in Arizona is shown at left, and is an example of the way an impact crater looks when it has a young age on Earth. The desert in Arizona has had little impact on the crater since it was first formed. Many other craters have been eliminated from Earth's surface by steady erosion over time.**

You can see from the examples of impact craters that asteroids, meteors, and comets have struck Earth in the past and will do so again in the future. A large object striking Earth or even just coming very close can have a major effect on us. Our institutions such as hospitals and food supply could be severely affected. It is important to have a warning system set up to give us time to deal with an imminent impact. While caution is wise, you don't need to be concerned about colliding with a space object in the near future; on average, big impacts occur about once every 50 million years.

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*Image Credit: NASA. Source: NASA. "Manicouagan Reservoir." *Solar System Exploration: Multimedia: Gallery.* 2011. http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=792. Reproduced with permission.

**Photo Credit: NASA/D. Roddy LPI. Source: Plumb, Donald, et al. *Nelson Science 9*. Scarborough, ON : Nelson-Thomson Learning, 1999. Figure 4. 432. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff.*

There has been an impact hazard scale developed—called the Torino Scale after the Italian city in which it was adopted—and this scale can provide an impact hazard NUMBER from 0 to 10 that assesses the possible risks of impact and possible effects:

The Torino Impact Hazard Scale*

Assessing Asteroid And Comet Impact Hazard Predictions In The 21st Century

No Hazard (White Zone)	0	The likelihood of a collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bodies that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.
Normal (Green Zone)	1	A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.
Meriting Attention by Astronomers (Yellow Zone)	2	A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.
	3	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.
	4	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.
Threatening (Orange Zone)	5	A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
	6	A close encounter by a large object posing a serious but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
	7	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.

continued

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* Source: NASA. "The Torino Impact Hazard Scale." *Near-Earth Object Program*. http://neo.jpl.nasa.gov/torino_scale.html (27 Apr. 2011). Courtesy of NASA.

Certain Collisions (Red Zone)	8	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.
	9	A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.
	10	A collision is certain, capable of causing global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

Note: the Torino Scale was recently revised according to this recent publication:

Morrison, D., Chapman, C. R., Steel, D., and Binzel R. P. "Impacts and the Public: Communicating the Nature of the Impact Hazard" In Mitigation of Hazardous Comets and Asteroids,(M.J.S. Belton, T.H. Morgan, N.H. Samarasinha and D.K. Yeomans, Eds), Cambridge University Press, 2004.

Funding to search for, and hopefully to detect, possible impactors from outer space is small, but there are organizations that are dedicated to keeping an eye out for us. A list of such organizations is shown below.

- Spacewatch
- Spaceguard Foundation
- Near-Earth Asteroid Tracking Program
- Lowell Observatory Near-Earth Object Search

Online Resource

The following website provides information about asteroids and the potential for collisions with Earth.

- About.com
  http://space.about.com/od/nearearthobjects/Near_Earth_Objects_and_Impact_Dangers.htm

Colonies in Space

Many see colonizing space as a natural "next step" in the development of an international presence in space. The United States has received a presidential mandate to place human colonies on the Moon and Mars by about the year 2020. This vision will certainly create an energy and need determination and generous funds to meet the challenge.

Colonization has attracted attention for many reasons:

- Space colonies establish political and strategic superiority much as new world colonies did in the fifteenth and sixteenth centuries. You may want to think about whether this should happen for these reasons.
- Space colonies permit a new "jumping off point" to frontiers that generate new understandings and ways of thinking.
- Space colonies provide access to resources that may be scarce on Earth.
- Space colonies provide opportunities for rapid and important developments in science and engineering.

Our two closest neighbours are the Moon and Mars. We have placed astronauts on the Moon already—we did that six times some 40 years ago. The Moon, however, presents some disadvantages in establishing a colony. The Moon has no readily accessible water, and no sources of oxygen since there is no atmosphere and no oxygen-bearing compounds in the Moon surface.

Mars is farther away than the Moon, making time of travel a greater consideration. There are newer methods of propulsion that would reduce the time needed to reach Mars, but the distance is huge and it is a long flight for a human crew—about 18 months travel each way. While establishing a colony on Mars would be more complex than any space program yet, Mars does offer a more agreeable ecology than the Moon. Mars has an atmosphere, but a thin one dominated by carbon dioxide. The atmosphere is composed mainly of carbon dioxide (95%) which would provide all the oxygen we need for life. The other trace elements are nitrogen gas (2.7%), argon gas, oxygen gas, and water vapour. The latest missions to Mars indicate there could well be abundant water ice just under the surface water on Mars. This could then be the source for liquid water.

Mars has had many probes sent to explore its environment. The International Space Station has been assembled. A new era of international cooperation is encouraging anyone who is interested in space travel to "get on board."

Summary

The celestial bodies of outer space have captured people's imaginations. We debate whether life exists on them, whether they may have any impact (literally) on our planet, and whether it is possible to set foot on these distant worlds. In your next assignment, you will explore what it might be like to plan a Canadian mission to the planet Mars.

Assignment 4.8: Colony Project (12 marks)

Your project for space science is an interesting one. Canada is sending a team to Mars to establish a colony. You are the project coordinator. Your task is look after the main parts of the mission. You have experts that will look after the details. You will be responsible for oversight of the following:

- transportation to Mars
- starting the colony
- looking after daily needs for long-term survival

Your project should have the following:

- A 250-word report that is done on a word processor. The report should have a line spacing of 1.5 and a 12 point font. At the end of your report, you should include a list of references that you used.
- A 100-word letter home that will be sent as an email through communication satellites. Your letter home will describe a typical day at the colony, what you see as you look out from Mars into space, how the trip to Mars went, and any other topics you think are relevant.
- Submit your Mars Station report and letter to the Distance Learning Unit for evaluation.
- You will be evaluated according to the following rubrics.

Marking Rubric

250-Word Report

Content	Criteria	/6
Students compose fictional accounts of mission to other worlds, including the type of environments encountered, atmospheric composition, geology, potential for novel life forms, et cetera, **with respect to transportation**.	2 – Summarizes potential characteristics of life on Mars, remaining as scientifically credible as possible (i.e., referencing a variety of sources). 1 – Explains potential characteristics of life on Mars using information from the course. 0 – Identifies potential characteristics of life on Mars, not taking into account scientific credibility.	/2
Students compose fictional accounts of mission to other worlds, including the type of environments encountered, atmospheric composition, geology, potential for novel life forms, et cetera, **with respect to starting a colony**.	2 – Summarizes potential characteristics of life on Mars, remaining as scientifically credible as possible (i.e., referencing a variety of sources). 1 – Explains potential characteristics of life on Mars using information from the course. 0 – Identifies potential characteristics of life on Mars, not taking into account scientific credibility.	/2
Students compose fictional accounts of mission to other worlds, including the type of environments encountered, atmospheric composition, geology, potential for novel life forms, et cetera, **with respect to potential daily encounters**.	2 – Summarizes potential characteristics of life on Mars, remaining as scientifically credible as possible (i.e., referencing a variety of sources). 1 – Explains potential characteristics of life on Mars using information from the course. 0 – Identifies potential characteristics of life on Mars, not taking into account scientific credibility.	/2

100-Word Letter

Content	Criteria	/6
Students describe their typical day at the Mars colony, including the view into space and events during the trip to the planet.	2 – Summarizes potential characteristics of life on Mars, remaining as scientifically credible as possible (i.e., referencing a variety of sources). 1 – Explains potential characteristics of life on Mars using information from the course. 0 – Identifies potential characteristics of life on Mars, not taking into account scientific credibility.	/3
Students discuss additional relevant topics of their choosing.	2 – Summarizes potential characteristics of life on Mars, remaining as scientifically credible as possible (i.e., referencing a variety of sources). 1 – Explains potential characteristics of life on Mars using information from the course. 0 – Identifies potential characteristics of life on Mars, not taking into account scientific credibility.	/3

LESSON 15: EXPLORING THE UNIVERSE REVIEW

Lesson Focus

This lesson contains a review learning activity that (together with Learning Activity 4.9 and Learning Activity 4.12) you can use to test your knowledge of the concepts within this module.

Learning Activity 4.14: Self-Quiz 3

Matching

Match the letter of the phrase/sentence in the right column with the appropriate word(s) in the left column. Note there are more answers in the right column than required.

continued

Learning Activity 4.13 (continued)

______ big bang theory

______ terrestrial planets

______ lunar

______ waxing

______ asteroid

______ meteor

______ apparent magnitude

______ nebula

______ neutron star

______ quasar

______ luminosity

______ solar mass

a. very small object in space that produces 100 times the energy of our whole galaxy
b. can produce a pulsar
c. Moon decreases in size until it forms new moon.
d. forms a white dwarf
e. Some of it survives the trip through Earth's atmosphere.
f. All stars start this way.
g. equals the mass of the Sun
h. refers to the brightness of a star as it appears to us
i. the inner four planets
j. the total amount of energy a star gives off per second
k. Moon increases in size as it approaches full moon.
l. completely burns up as it enters Earth's atmosphere
m. a small planet-like object located between Mars and Jupiter
n. The universe was formed this way at some point in time.
o. called the outer planets
p. having to do with the Moon

Short Answer

1. What did the background "noise" observed by Penzias and Wilson using their radio telescope tell scientists about the beginning of the universe?
2. Use the table at the end of the learning activity to answer the following questions.
   a. On which planet would you weigh the most?
   b. Which planet has the longest day?

continued

Learning Activity 4.13 (continued)

   c. Which planet has the greatest density?
   d. On which planet would the Sun’s rays be strongest?
   e. Which planet has a length of year most like ours?

3. We use a marble to represent Earth. Pick one of the objects (hot-air balloon, tennis ball, small ball bearing) to represent
   a. Jupiter
   b. Mercury
   c. Sun
4. Would a piece of a comet be considered a meteoroid? Explain.
5. Name the two parts of a comet.
6. How do the times for rotation of the Moon on its axis and its revolution around Earth compare?
7. Why is it easier for space objects to hit the Moon and make a crater than it is for the same space objects to hit Earth and make a crater?
8. How do stars produce their energy?
9. You see a red star and a blue star through your telescope. Which of the two would be hottest?
10. A spectroscope is used to view the spectrum from a star. Some black lines are seen on the colour spectrum. What do the black lines represent?
11. Saturn has a solar mass of 95.2. Explain what this tells us about Saturn.

Check the answer key.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Average distance from the Sun (millions of kilometres)	57.9	108.2	149.6	227.9	778.3	1 429	2 875	4 504
Revolution	59 days	224.7 days	365 days	687 days	11.86 years	29.46 years	84 years	165 years
Rotation	59 days	243 days	23 hours 56 minutes	24 hours 37 minutes	9 hours 55 minutes	10 hours 39 minutes	17.3 hours	17 hours 50 minutes
Average orbital speed (kilometres per second)	48	35	30	24	13	9.6	6.8	5.4
Equatorial diameter (kilometres)	4 880	12 100	12 756	6 794	142 984	120 536	51 100	49 200
Mass (Earth = 1)	.055	.815	1	.107	317.9	95.2	14.54	17.2
Density (water = 1)	5.4	5.3	5.5	3.9	1.3	.7	1.2	1.56
Surface gravity (Earth = 1)	.38	.91	1	.38	2.53	1.07	.91	1.16
Known satellites	0	0	1	2	16	17	15	2

MODULE 4 SUMMARY

Congratulations! You have finished the fourth module of Grade 9 Science.

Submitting Your Assignments

It is now time for you to submit Assignments 4.1 to 4.8 to the Distance Learning Unit so that you can receive some feedback on how you are doing in this course. Remember that you must submit all the assignments in this course before you can receive your credit.

Make sure you have completed all parts of your Module 4 assignments and organize your material in the following order:

- Module 4 Cover Sheet (found at the end of the course Introduction)
- Assignment 4.1: Measuring Altitude
- Assignment 4.2: Locating Celestial Objects Using a System of Coordinates
- Assignment 4.3: Path of the Sun and the Moon
- Assignment 4.4: Monitoring the Retrograde Motion of the Planet Mars
- Assignment 4.5: Life on Mars
- Assignment 4.6: Measuring in Space
- Assignment 4.7: Stars
- Assignment 4.8: Mars Colony Project

For instructions on submitting your assignments, refer to How to Submit Assignments in the course Introduction.

Final Examination

Congratulations, you have finished Module 4 in the course. The final examination is out of 100 marks and worth 25% of your final mark. In order to do well on this examination, you should review all of your learning activities and assignments from Modules 1 to 4.

You will complete this examination while being supervised by a proctor. You should already have made arrangements to have the examination sent to the proctor from the Distance Learning Unit. If you have not yet made arrangements to write it, then do so now. The instructions for doing so are provided in the Introduction to this module.

You will need to bring the following items to the examination: some pens and/or pencils (2 or 3 of each), some blank paper, a calculator, and a ruler.

A maximum of **2 hours** is available to complete your final examination. When you have completed it, the proctor will then forward it for assessment. Good luck!

Final Practice Examination and Answer Key

To help you succeed in your examination, a practice examination can be found in the learning management system (LMS). The final practice examination is very similar to the actual examination that you will be writing. The answer key is also included so that, when you have finished writing the practice examination, you can check your answers. This will give you the confidence that you need to do well on your examination. If you do not have access to the Internet, contact the Distance Learning Unit at 1-800-465-9915 to get a copy of the practice examination and the answer key.

To get the most out of your Final Practice Examination, follow these steps:

1. Study for the Final Practice Examination as if it were an actual examination.
2. Review those learning activities and assignments from Modules 1 to 4 that you found the most challenging. Reread those lessons carefully and learn the concepts.
3. Ask your learning partner and your tutor/marker for any help you need.
4. Review your lessons from Modules 1 to 4, including all of your notes, learning activities, and assignments.
5. Bring the following to the Final Practice Examination: pens/pencils (2 or 3 of each), blank paper, a calculator, and a ruler.

6. Write your Final Practice Examination as if it were an actual examination. In other words, write the entire examination in one sitting, and don't check your answers until you have completed the entire thing.
7. Once you have completed the entire examination, check your answers against the answer key. Review the questions that you got wrong. For each of those questions, you will need to go back into the course and learn the things that you have missed.

Notes

MODULE 4

Learning Activity Answer Key

MODULE 4
LEARNING ACTIVITY ANSWER KEY

LESSON 1

Learning Activity 4.1: Astronomy in Ancient Times

1. Read your notes and any reference material you have that describes the meaning of **geocentric**, **retrograde**, and **epicycle**. Once you have read your reference material, write in your own words the meaning of the terms.

   Answers will vary.

   a. Geocentric: A model of the universe that positions Earth at the centre of all stars and planets. Celestial bodies, including the Sun, rotate around Earth.

   b. Retrograde: The apparent back-and-forth motion of planets, as seen from Earth's surface.

   c. Epicycle: Literally, "little circles." The Greek astronomer Ptolemy proposed a theory to explain the retrograde motion of planets that involved epicycles.

2. a. How did Aristotle and Aristarchus differ in their theories about the structure of the universe?

   Aristotle proposed that the universe was in the form of a perfect circle, and that Earth was a spherical ball located at the direct centre. Aristotle also proposed that the stars, planets, and Sun were located within spheres that rotated around Earth. The retrograde motion of planets was due to their motion within these smaller spheres.

   Aristarchus proposed that Earth and other planets revolved around the Sun. Aristarchus also emphasized that the Sun was a giant ball of fire.

   b. Why was it difficult for the scholars of ancient Greece to decide whether they should believe and accept Aristotle's or Aristarchus's theory about the structure of the universe?

   Aristarchus's model, in which Earth moved through space around the Sun, was difficult to accept because it didn't seem to fit observations. It seemed reasonable that if Earth was moving through space, people should feel the movement. Additionally, Aristotle's reputation as a great philosopher helped to cement his theory as the "best" model. Since Aristarchus was born almost 70 years after Aristotle, he grew

up in a generation that had already accepted Aristotle's geocentric model of the universe, perhaps making his contrary model all the more difficult to accept.

LESSON 2

Learning Activity 4.2: Astrolabe Construction

Because of the nature of this learning activity, no answer key is provided.

Learning Activity 4.3: Using an Astrolabe

Because student responses to this learning activity will vary, no answer key is provided.

LESSON 3

Learning Activity 4.4: Altitude and Azimuth

1. What are the coordinates of a star that is located southeast and is halfway from the horizon to the zenith?

   The star's azimuth is 135°, and the altitude is 45°.

2. What are the coordinates of the moon when it is due east and 20° above the horizon?

   The azimuth of the Moon is 90°, and the altitude is 20°.

3. The North Star is called Polaris. Wherever you are located in the Northern Hemisphere, Polaris is always due north. The altitude of Polaris is always equal to the latitude on Earth's surface from where you are observing the star, as long as you are north of the equator.

   What are the coordinates of Polaris if you are located at Norway House, Manitoba, where the latitude is 53.5°?

   The azimuth of Polaris is 0°, and the altitude is 53.5°.

4. What are the coordinates for Polaris where you live?

   Polaris will always be located at an azimuth of 0° in the Northern Hemisphere. The altitude will vary depending on the latitude of your location. Some common latitudes are listed below:

   Brandon = 49° North

   Churchill = 58° North

   Dauphin = 51° North

   Flin Flon = 54° North

   Portage La Prairie = 49° North

   The Pas = 53° North

   Winnipeg = 49° North

LESSON 4

Learning Activity 4.5: Observing and Charting the Moon

Because student responses to this learning activity will vary, no answer key is provided.

LESSON 5

Learning Activity 4.6: Heliocentric Model

1. What two names are given to Ptolemy's model of the universe in this lesson?

   Ptolemy's model of the universe is referred to as the "geocentric model" and the "ptolemic model."

2. Briefly describe Ptolemy's model of the universe.

   In Ptolemy's model of the universe (which was heavily influenced by Aristotle's theories), the universe was a perfect circle with Earth at the centre. The planets and stars travelled in crystalline, transparent spheres around Earth. The space in between was filled with a substance called ether.

3. Over what period of time was Ptolemy's model of the universe accepted as the correct one?

   Ptolemy's model of the universe was accepted as "correct" (in Islamic and European societies) for approximately 1400 years, about 150 CE to 1550 CE.

4. Why was Ptolemy's model accepted for so long?

   Several factors lead to Ptolemy's long-lasting model of the universe. One reason was that early astronomy was not governed by a "scientific method," where a hypothesis would be tested through observation and experimentation.

   Second, the reputation of a scientist or philosopher could very easily bolster the popularity and spread of a theory. Including Ptolemy's writings in "the great work" (the *Almagest*) would have given it very authoritative credibility.

   Third, other models of the universe created tensions with long-held religious institutions. Theories contrary to the church's official position were viewed as suspicious and were strongly opposed.

   Finally, early astronomers performed all their observations and calculations without the aid of a telescope.

5. How did Copernicus's model for the universe differ from Ptolemy's model?

   In Copernicus's model of the universe, the Sun was located at the centre of the solar system, with Earth moving around it.

6. Why wasn't Copernicus's theory readily accepted?

   Copernicus proposed a new model of the universe into a culture very steeped in tradition. If the geocentric model of the universe could be proven "incorrect," people could be inclined to question many more widely accepted "beliefs."

7. What stirred Galileo's interest in astronomy?

   The development of the telescope stirred Galileo's interest in astronomy.

8. Why was Galileo able to reject Aristotle's assertion that air had no weight with such confidence?

   By performing an experiment where he compared the weight of an empty ball with one filled with air, Galileo was able to demonstrate that air did have weight.

9. How did the telescope allow Galileo to demonstrate that celestial objects were not perfect?

   When Galileo used a telescope to observe the Moon, he could see that it contained craters, valleys, and mountains. Its surface was not a perfect sphere.

10. If Tycho Brahe had lived longer, why would he be disappointed with Kepler?

    Tycho Brahe was a passionate supporter of the geocentric model, and he wanted to prove Copernicus wrong. Johannes Kepler, on the other hand, agreed with Copernicus's heliocentric model, and used Brahe's data to research and support this view of the solar system.

11. What breakthrough allowed Kepler to fit Tycho's measurements to Copernicus's heliocentric model?

    When Kepler realized that planets travelled in elliptical orbits around the Sun, as opposed to circular orbits, he was able to fit Tycho's measurements to the heliocentric model.

12. Newton was able to satisfy Kepler's question "What force moves the planets around the Sun?" How did he do this?

    Newton determined that the force pulling objects towards Earth (gravity) was also responsible for pulling planets around the Sun. Planets do not fall into the Sun like an object falls into Earth because planets move at quite high velocities that cause them to move sideways as they move down, resulting in movement around the Sun.

LESSON 6

Learning Activity 4.7: Modern Astronomy

1. What event in Herschel's life allowed him to pursue astronomy full-time?

   When Herschel discovered the planet Uranus, he was awarded a grant by King George III of England that enabled him to pursue astronomy full-time.

2. What system did Herschel use to count stars?

   Herschel counted stars via the star-gauging method. This involved sectioning off small parts of the sky and counting the stars in that individual section.

3. What name is given to Herschel's "powder puff"?

   Today, Herschel's "powder puffs" are known as galaxies.

4. What were the hazy patches of light seen by Herschel and other astronomers called?

   The hazy patches of light are now called nebulae.

5. What celestial objects made up the hazy patches of light?

   The hazy patches of light are actually other galaxies.

6. Do some research on the electromagnetic spectrum. Use books and the Internet as your sources.

   a. Draw a diagram of the three parts of the electromagnetic spectrum and use the following terms to label the diagram:

      microwaves, radio waves, gamma rays, visible light, infrared radiation, ultraviolet radiation, X-rays

   b. Label the ends of the spectrum with the labels "highest frequency" and "lowest frequency."

   c. Label the ends of the spectrum with the labels "longest wavelength" and "shortest wavelength."

Electromagnetic Spectrum	
Highest Frequency/Shortest Wavelength ➜	**Gamma Rays** **X-Rays** **Ultraviolet Radiation** **Visible Light** **Infrared Radiation** **Microwaves**
Lowest Frequency/Longest Wavelength ➜	**Radio Waves**

   d. At what speed through space will the following travel?

      Radio waves, Visible light, Gamma rays

      In space, radio waves, visible light, and gamma rays all travel at 300 000 000 metres per second (the speed of light in a vacuum).

   e. Which type of electromagnetic radiation would you use the following telescopes to view?

Reflecting telescope:	**Visible light**
High-energy telescope:	**Gamma rays**
Radio telescope:	**Radio waves**

LESSON 7

Learning Activity 4.8: Celestial Navigation

1. Early seafarers used navigational aids other than stars to help find their position.
   a. Name two navigational aids used.
   Landmarks such as rock formations and shallow areas of water were two navigational aids used.
   b. Why were the early ships often limited in their navigation?
   Because there are no landmarks out at sea, early ships had to stay close to coastlines in order to monitor coastal landmarks.
   c. What were some of the dangers associated with early navigation?
   If weather conditions such as fog or rain obscured your surroundings, you would not be able to navigate by landmarks.
   d. How were landmarks transmitted from one generation to the next?
   The older generation would memorize landmarks and pass their knowledge on to their children.

2. Why is it necessary to use latitude and longitude when travelling far away from familiar territory?

   Latitude and longitude allow travellers to locate their position even while in unfamiliar territory, where there are no landmarks by which to navigate.

3. What does latitude measure?

   Latitude measures your position with respect to Earth's equator and poles.

4. What does longitude measure?

   Longitude measures your position with respect to the prime meridian.

5. Use an atlas to determine the approximate latitude and longitude for The Pas and Brandon.

   The Pas = 53° North, 101° West
   Brandon = 49° North, 99° West

6. What is the longitude measurement at Greenwich, England?

   Greenwich, England, is located at 0° longitude.

7. What two time measurements are needed to determine the longitude of a ship at sea?

   A ship at sea must know the current time at Greenwich, England, and the local time on the ship.

8. **Student answers will vary.**

Learning Activity 4.9: Self-Quiz 1

1. Match the name of the person in the right column with the most appropriate phrase in the left column.

   Greek astronomer who

j. Thales	moved away from using mythology to explain natural occurrences.
a. Aristotle	developed the concept of a celestial sphere.
b. Aristarchus	was first to put forward a sun-centred model of solar system.
c. Ptolemy	used a series of epicycles to explain retrograde motion of planets.
i. Hipparchus	developed a huge star chart complete with categories of star brightness.
d. Copernicus	is considered to be the first to present mathematical evidence that planets orbit the Sun.
f. Galileo	was first to use a telescope to observe the planets and moons.
e. Kepler	developed the laws of planetary motion.
h. Newton	developed the Law of Universal Gravitation.
g. Herschel	is regarded as the first of the modern astronomers.

2. a. Ancient astronomers observed the wandering motion of some objects in the sky and called the objects **constellations**.
   b. A student measured a planet at one fist above the horizon. What is the approximate angle the planet makes with the horizon? **10°**
   c. The astrolabe below makes an angle of **28°** when measuring the height of the tree.
   d. Herschel discovered a new planet and named it Georgium in honour of the king of England, but everyone now calls the planet **Uranus**.
   e. Our galaxy is given the common name **Milky Way**.
   f. Aristotle believed the space between the planets, Sun, and stars was filled with a substance called **ether**.

LESSON 9

Learning Activity 4.10: Triangulation

Because of the nature of this learning activity, no answer key is provided for numbers 1 to 11.

12. If you wanted to measure the distance to a star, how would you get the huge baseline that would be required?

    The diameter of Earth's orbit would become your baseline.

LESSON 10

Learning Activity 4.11: Objects in Space

1. What other name is given to a moon that travels around a planet?

   Satellite is another name given to a moon.

2. Compare the time of rotation of the Moon to its time of revolution.

   The Moon rotates on its axis once every 27 days. It also revolves around Earth once every 27 days.

3. What determines the phases of the Moon?

   The phases of the Moon are determined by its position in relation to Earth and the Sun.

4. What Roman goddess' name gave our moon its name?

   Luna gave our moon its name.

5. Most asteroids are located between which two planets?

   Most asteroids are located between Mars and Jupiter.

6. What name is given to the band of asteroids?

   The Asteroid Belt is the name given to the band of asteroids between Mars and Jupiter.

7. What name is given to a space object once it enters Earth's gravity?

   A space object is called a meteoroid once it enters Earth's gravity.

8. What name is given to the objects that burn up in Earth's atmosphere?

   Objects that burn up in Earth's atmosphere are called meteors.

9. What are two parts of a comet?

   The head/coma and the tail are the two parts of a comet.

10. Research and describe what might happen if a giant meteorite struck Earth. Choose a place where the meteorite hits land.

    The possible consequences of a meteorite impact on land include

    - **the creation of a crater at the point of impact**
    - **a "fireball" of heat energy expanding away from the impact point, igniting grass, clothing, and trees**
    - **release of shockwaves through the ground that could topple buildings**
    - **the release of shockwaves through the air that could collapse buildings and highways, knock down trees, and toss around cars and trucks**

11. What evidence do we have that space objects have hit the Moon?

    There are numerous impact craters all over the surface of the Moon.

12. **Student answers will vary.**

Learning Activity 4.12: Self-Quiz 2

1. You are located on the ocean and need to determine your longitude. You could use a

   b. chronometer

2. Cosmology refers to

   a. a study of the beginnings of the universe

3. If you were located on the North Pole and determined the altitude of Polaris, you would have a reading of

   c. 90°

4. Light travels from the Sun to Earth.

   c. The distance is called an astronomical unit.

5. Match the letter of the best choice in the right column with the space provided in the left column.

a. North Star	Polaris
g. used by ancient cultures for help in navigation	Constellations
c. a measure of the angle between equator and North/South Pole	Latitude
f. the galaxy that we occupy	Milky Way
b. apparent backward motion of a planet	Retrograde Motion
d. used as an indirect method to measure distance of stars	Parallax
e. distance light travels in one year	Light Year

6. A navigator measures the North Star and measures its altitude at 28 degrees and its azimuth at 43 degrees. The latitude of the navigator is **43 degrees**.

7. Why is the accurate measuring of the seasons important?

   Depending on the season and hemisphere, different constellations will be visible in the night sky.

8. If Earth's axis doesn't wobble back and forth, how is it possible for Earth to be inclined toward the Sun in the summer and away from the Sun in the winter in the Northern Hemisphere? Diagrams would be helpful in answering this question.

   Earth's axis is fixed; the planet does not tilt or readjust its angle; however, as it rotates around the Sun, the angle at which each hemisphere is exposed to sunlight changes. When the Northern Hemisphere is tilted towards the Sun, it will experience summer. At the same time, the Southern Hemisphere will be tilted away from the Sun, leaving it in winter.

9. What unit of measure would you use when measuring the distance from our neighbouring galaxy, Andromeda, to us?

   I would use light years to measure that distance.

10. How is it possible to get a large base for measuring the distance to a star by triangulation?

    To measure the distance to a star through triangulation, you must use the diameter of Earth's orbit as your base.

11. a. What is the length of the baseline if the distance from Earth to Sun is 163 000 000 kilometres?

       The length of the baseline is 326 000 000 kilometres.

    b. What is the distance from Earth to the star? Use a scale diagram.

       The distance from Earth to the star is approximately 960 237 055 kilometres.

LESSON 12

Learning Activity 4.13: Technology in Space

1. Why is air necessary for aircraft flight?

   Air is necessary for aircraft flight because engines and turbines on aircraft require oxygen for their combustion reactions. It is also necessary to provide lift on the wings of an aircraft. Both the horizontal and vertical movement of an aircraft rely on air.

2. Spacecraft flight doesn't need air. Explain this statement.

   Spacecraft require oxygen for the combustion reaction within their rockets. However, rockets carry their own oxygen supply, making them an entirely self-contained propulsion system.

3. Why do rockets need escape velocity to travel into space?

   Rockets must achieve escape velocity in order to overcome Earth's gravitational pull.

4. Why is it difficult to use communication satellites with low Earth orbit satellites?

   Because of the high speeds at which low Earth orbit satellites travel, any signals sent from these satellites would require a very complex and expensive tracking system.

5. Explain the Canadian connection to the RADARSAT satellite.

   RADARSAT is a Canadian satellite system used to map Earth's surface.

6. What are telecommunications?

   Telecommunications are long-distance communications systems.

7. What is a geosynchronous orbit?

   A satellite travels at a geosynchronous orbit if it travels at the same speed as Earth. This will synchronize its movement with Earth, maintaining it at an exact position above the planet.

8. Why is a geosynchronous orbit satellite good for communications?

   A geosynchronous orbit satellite will maintain an orbit above a specific location. This makes it unnecessary to track the satellites. Satellite dishes can be set once and then left alone.

9. What is GPS used for?

   Global Positioning Systems are used for navigation.

10. What is the International Space Station?

    The International Space Station is a cooperative venture of the United States, Europe, Canada, Russia, and Japan. It is an orbiting research laboratory, first launched in 1998.

11. Why are space probes often used instead of staffed spacecraft?

    Space probes are less expensive and can travel incredible distances without being required to return to Earth.

12. Name two probes used to explore Mars.

    The Mars probes include the *Pathfinder*, *Viking 1* and *Viking* 2, the Mars Exploration Rovers *Spirit* and *Opportunity*, and the *Phoenix*.

13. Name three problems with telescopes that must look through Earth's atmosphere.

    Telescopes looking through Earth's atmosphere must contend with light pollution, the absorption of light into the atmosphere, and the bending/distortion of light through the atmosphere.

14. When was the Hubble Space Telescope launched?

    The Hubble Space Telescope was launched on April 24, 1990.

15. What was wrong with the Hubble Space Telescope initially and how was it repaired?

    Initially, the lenses of the Hubble Telescope were improperly ground, producing fuzzy images. Between 1993 and 2009, astronauts added equipment to the telescope, including corrective lenses to bring Hubble's images into clearer focus.

LESSON 15

Learning Activity 4.14: Self-Quiz 3

Matching

Match the letter of the phrase/sentence in the right column with the appropriate word(s) in the left column. Note there are more answers in the right column than required.

n.	**The universe was formed this way at some point in time.**	big bang theory
i.	**the inner four planets**	terrestrial planets
p.	**having to do with the Moon**	lunar
k.	**The Moon increases in size as it approaches full moon.**	waxing
m.	**a small, planet-like object located between Mars and Jupiter**	asteroid
l.	**completely burns up as it enters Earth's atmosphere**	meteor
h.	**refers to the brightness of a star as it appears to us**	apparent magnitude
f.	**All stars start this way.**	nebula
d.	**forms a white dwarf**	neutron star
a.	**very small object in space that produces 100 times the energy of our whole galaxy**	quasar
j.	**the total amount of energy a star gives off per second**	luminosity
g.	**equals the mass of the Sun**	solar mass

Short Answer

1. What did the background "noise" observed by Penzias and Wilson using their radio telescope tell scientists about the beginning of the universe?

   The background "noise" was identified as cosmic microwave background radiation coming from outside our galaxy. This is believed to be leftover radiation from an explosion that filled the universe at the beginning of its existence.

2. Use the table at the end of the learning activity to answer the following questions.
   a. On which planet would you weigh the most? **Jupiter**
   b. Which planet has the longest day? **Venus**
   c. Which planet has the greatest density? **Earth**
   d. On which planet would the Sun's rays be strongest? **Mercury**
   e. Which planet has a length of year most like ours? **Venus**

3. We use a marble to represent Earth. Pick one of the objects (hot-air balloon, tennis ball, small ball bearing) to represent
   a. Jupiter **tennis ball**
   b. Mercury **small ball bearing**
   c. Sun **hot-air balloon**

4. Would a piece of a comet be considered a meteoroid? Explain.

   A comet could only be considered a meteoroid if it were caught in Earth's gravity.

5. Name the two parts of a comet.

   A comet is made of the head/coma and tail.

6. How do the times for rotation of the Moon on its axis and its revolution around Earth compare?

   The times for the Moon to rotate on its axis and for the Moon to revolve around Earth are equal in length.

7. Why is it easier for space objects to hit the Moon and make a crater than it is for the same space objects to hit Earth and make a crater?

   Because the Moon has no atmosphere, there is nothing to slow down a space object's speed as it approaches the Moon.

8. How do stars produce their energy?

   Stars produce their energy through the nuclear fusion of hydrogen into helium.

9. You see a red star and a blue star through your telescope. Which of the two would be hottest?

   The blue star would be the hottest when compared with a red star.

10. A spectroscope is used to view the spectrum from a star. Some black lines are seen on the colour spectrum. What do the black lines represent?

    The black lines on the spectroscope represent the chemical elements that make up the gas surrounding the star.

11. Saturn has a solar mass of 95.2. Explain what this tells us about Saturn.

    This tells us that the mass of the planet Saturn is 95.2 times greater than the mass of the Sun.

GRADE 9 SCIENCE (10F)

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Notes

GRADE 9 SCIENCE

Final Practice Exam

GRADE 9 SCIENCE

Final Practice Exam

Name: ____________________

Student Number: ____________________

Attending ☐ Non-Attending ☐

Phone Number: ____________________

Address: ____________________

____

____

For Marker's Use Only

Date: ____________________

Final Mark ________ /100 = ________%

Comments:

Instructions

- You have a maximum of 2 hours to write this exam.
- Supplies required: calculator, paper, and ruler

Multiple Choice

Each question has a single best answer. Make your choice by circling the letter beside your answer. **(*18 x 1 mark each = 18 marks*)**

1. In Western history, the first recorded scientist to propose that Earth revolved around the Sun was
   a. Galileo
   b. Copernicus
   c. Ptolemy
   d. Aristarchus

2. Sperm and egg cells are referred to as
   a. gametes
   b. zygotes
   c. diploid cells
   d. homologous cells

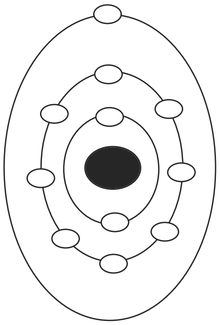
3. Which of the following elements has a total of six electrons in its valence shell?
   a. nickel
   b. chromium
   c. sulphur
   d. bromine
4. Jupiter, Saturn, Neptune, and Uranus are considered a family known as
   a. the galactic planets
   b. gas giant planets
   c. terrestrial planets
   d. solar planets
5. What is the azimuth of Polaris when observed from Winnipeg, Manitoba?
   a. 0°
   b. 15°
   c. 35°
   d. 50°
6. An example of a naturally occurring diatomic molecule is
   a. gold
   b. copernicium
   c. carbon dioxide
   d. hydrogen gas
7. Twelve coulombs of electric charge travels through a resistor which uses 24 joules of energy. What is the potential difference across the resistor?
   a. 2 J/C
   b. 12 J/C
   c. 36 J/C
   d. 288 J/C
8. Ernest Rutherford is credited for the discovery of
   a. the moons of Jupiter
   b. the nucleus of the atom
   c. deoxyribonucleic acid (DNA)
   d. the piezoelectric effect

Name: ____

9. Human egg cells are produced in the
    a. ovaries
    b. vagina
    c. cervix
    d. uterus

10. The unit for measuring electric current is the
    a. joule
    b. ohm
    c. ampere
    d. tesla

11. The diagram below represents



    a. an atom of magnesium
    b. a molecule of sodium
    c. an alkali metal
    d. a chalcogen

12. How long does it take the Moon to revolve around Earth?
    a. 24 hours
    b. 27 days
    c. 12 days
    d. 1 week

13. A mother is homozygous recessive for a sex-linked trait. Which statement is true?
    a. Half of her daughters will display the dominant phenotype.
    b. All of her daughters will display the recessive phenotype.
    c. All of her sons will display the dominant phenotype.
    d. All of her sons will display the recessive phenotype.

14. Stars such as our Sun produce their energy
    a. through the nuclear fission of helium into hydrogen
    b. through the nuclear fusion of hydrogen into helium
    c. through the nuclear fission of hydrogen into helium
    d. through the combustion of hydrocarbons

15. A diploid human cell contains
    a. 64 chromosomes
    b. 23 pairs of chromosomes
    c. 46 pairs of chromosomes
    d. 23 chromosomes

16. A rod that has been negatively charged touches an electroscope.
    a. Negative charges move out of the electroscope.
    b. Positive charges move out of the electroscope.
    c. Negative charges move into the electroscope.
    d. Positive charges move into the electroscope.

17. A metal that can be hammered into thin sheets demonstrates the property called
    a. malleability
    b. conductivity
    c. ductility
    d. lustre

18. Which scientist contributed to the first periodic table?
    a. Tycho Brahe
    b. Dimitri Mendeleev
    c. Aristotle
    d. Isaac Newton

Name: ____

Matching

Place a letter in the pace provided that gives the best match.
(*18 x 0.5 marks each = 9 marks*)

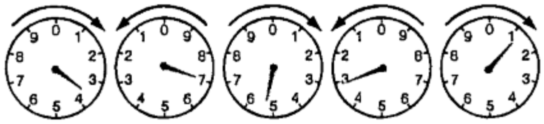
___ insulator
___ astrolabe
___ Bohr
___ chromosome
___ halogen
___ Galileo
___ Punnett square
___ light year
___ series circuit
___ atomic number
___ current
___ neutron
___ joule
___ potassium
___ electroscope
___ altitude
___ ovaries
___ Copernicus

a. discovered the moons of Jupiter
b. contain genes
c. developed a model of electron orbitals
d. the protons in a nucleus
e. chlorine
f. does not conduct electricity
g. provides only one path for electrical current
h. a vertical coordinate
i. the distance that light travels in 365 Earth days
j. the movement of electrons through a conductor
k. a model for predicting genotypes
l. female gonad
m. found in the nucleus of an atom
n. an alkali metal
o. detects electric charge
p. claimed that Earth orbited the Sun
q. Arabic instrument for observing stars
r. unit of energy

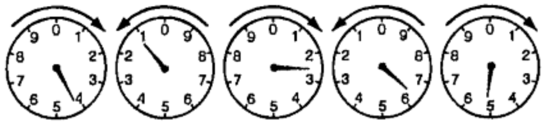
Short Answer (*29 marks*)

1. There are two hydro meter readings shown below. One meter reading is for July and the other is for August. (*4 marks*)

July:



August:



   a. What is the energy reading for July and August? Show the units. (*2 marks*)

   b. What is the energy consumption between July and August in this example? (*1 mark*)

   c. If the cost for energy were $0.24 per kilowatt hour, what will this household pay for energy? (*1 mark*)

2. Name two types of asexual reproduction. For each type, name one species that uses the method. (*4 marks*)

Name: ____

3. Identify the following elements by name and symbol. (*5 marks*)
   a. This element is the lightest in existence. ____________________
   b. This element is the most reactive non-metal. ____________________
   c. The atomic mass of this element is approximately 32. ____________________
   d. This element contains two more protons than nickel. ____________________
   e. On the periodic table, this element is located on the fourth period and the second family. ____________________

4. What is a phenotype? How is it different from a genotype? (*3 marks*)

____

____

____

____

____

5. What is a geosynchronous orbit, and how does it benefit telecommunications systems? (*2 marks*)

____

____

____

____

6. What is a nebula, and how does it form a star? (*3 marks*)

____

____

____

____

____

7. Fill in the blanks in the following sentences about cell division. (*5 marks*)

   Mitosis takes place in ________________ cells, while meiosis occurs in ________________ cells. Mitosis produces two ________________ cells, while meiosis produces a total of ______ cells, each with a ________________ chromosome count.

8. Use the Energuide symbol below to answer the following questions. (*3 marks*)

This appliance model # 1234567890 uses 123 kWh of electricity per month when tested in accordance with CSA standards.

ENERGUIDE

Cet appareil, de modèle n° 1234567890 vérifié conformément aux normes de l'ACNOR, consomme 123 kWh d'électricité par mois.

   a. How much energy would be used by this appliance in a typical month of use?

   b. If you were paying 7.5 cents per kWh for electrical energy in your area, what would it cost to use this appliance for three months?

Diagrams and Long Answers (*44 marks*)

1. In a species of dog, the gene for long hair (H) is dominant over the gene for short hair (h). A licensed breeder mates a long-haired male (Hh) with a long-haired female (Hh). (*7 marks*)

   a. Draw a Punnett square showing the potential genotypes of this pairing's offspring. (*1 mark*)

Name: ____

b. What are the possible genotypes of the offspring? In what percentages are they predicted to appear? (*3 marks*)

____

____

____

____

c. What phenotypes will the puppies display, and in what percentage? (*2 marks*)

____

____

____

d. How can the breeder alter the pairing to ensure that only long-haired puppies are born? (*1 mark*)

____

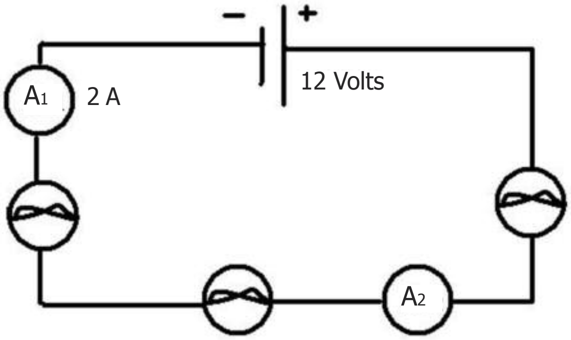
____

2. Draw a Bohr atom of fluorine. (*6 marks*)

a. Draw the atom, labelling the nucleus and one of the electrons. (*2 marks*)

b. How many neutrons are there in fluorine? ______________________ (*1 mark*)
c. What is the mass number for fluorine? ______________________ (*1 mark*)
d. To what family does fluorine belong? ______________________ (*1 mark*)
e. What is one trait shared by this family?
____ (*1 mark*)

3. Use the diagram below to answer the following questions. (*5 marks*)



a. Are the three bulbs connected in series or parallel? ______________________

b. What is the reading in A2? ______________________

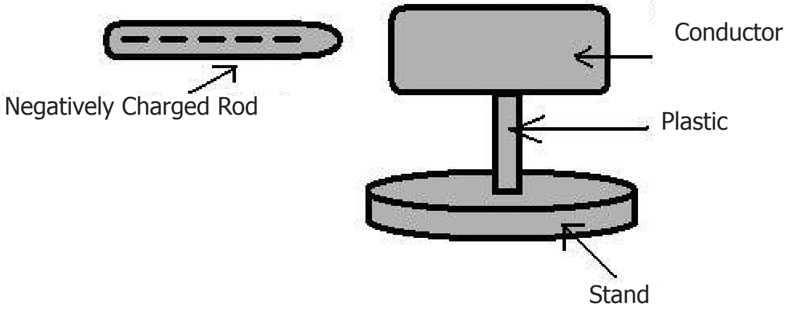
c. What is the total current in the circuit? ______________________

d. The three light bulbs all have the same resistance. What is the voltage across each of the light bulbs? ______________________

e. Draw an arrow on the diagram indicating the direction of electron flow.

The arrow should point away from the negative terminal of the battery and towards the positive terminal.

4. Use the diagram below to answer the following questions. (*5 marks*)



a. Draw the charge distribution for the conditions shown on the conductor. (*2 marks*)

Name: ____

b. How would you give the conductor a permanent charge without moving the charged rod? (*1 mark*)

____

____

c. What charge would be left on the conductor after completing part (b)? (*1 mark*)

____

____

d. What name is given to this method of charging an object? (*1 mark*)

____

____

5. Describe how seasons are produced in the Northern Hemisphere. (*4 marks*)

____

____

____

____

____

____

6. Why are you unlikely to find snow in countries along the equator? (*2 marks*)

____

____

____

____

7. What is the purpose of mitosis and meiosis within the human body? (*2 marks*)

____

____

____

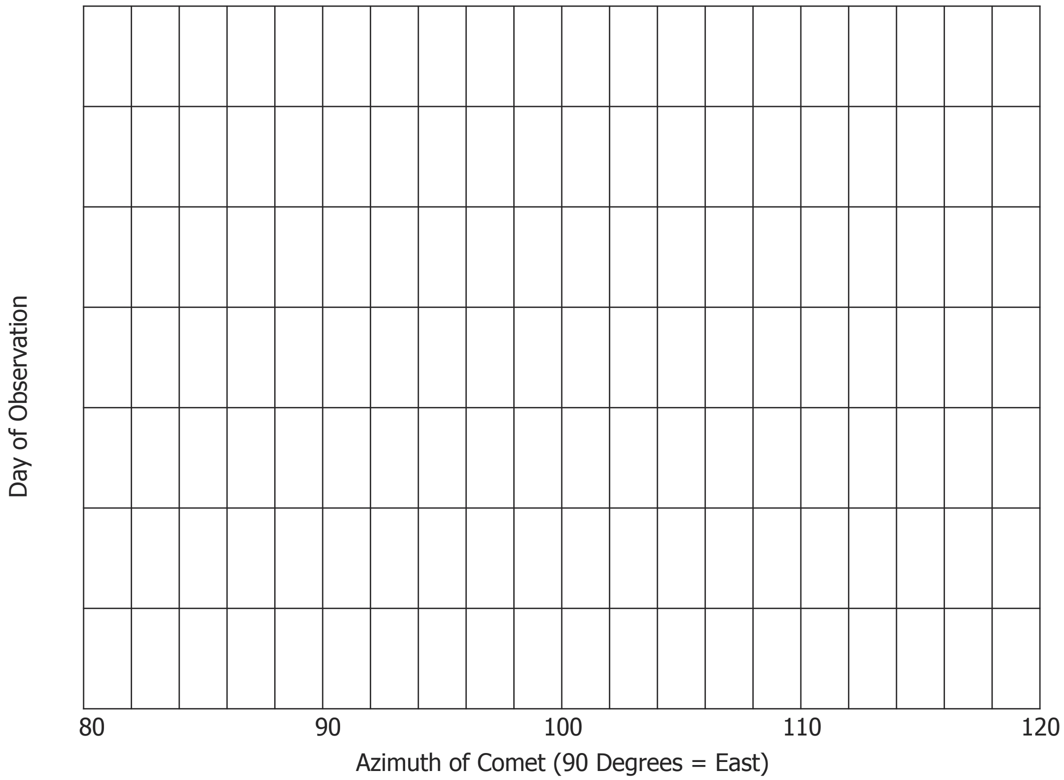
____

8. Darren has been observing a newly discovered comet through his telescope. (*8 marks*)

   a. Using the data provided in the table below, plot a graph showing the position of this new comet over the months of April to October. (*5 marks – 1 mark for title, 4 marks for graph*)

Observation Date	Comet’s Azimuth	Day within Study
April 1	102.0	0
April 15	95.0	15
May 1	88.0	30
May 15	84.0	45
May 30	83.0	60
June 14	84.0	75
June 29	87.0	90
July 14	92.0	105
July 29	98.0	120
August 13	99.0	135
August 28	91.0	150
September 12	85.0	165
September 27	80.0	180

Title: ____



b. When Darren shows his data table to Karen, she exclaims that he must have made an error, because the comet is clearly changing the direction of its revolution around the Sun. How might Darren defend his observations? (*3 marks*)

____

____

____

____

9. What are five indicators of a chemical change? (*5 marks*)

____

____

____

____

____

____

GRADE 9 SCIENCE

Final Practice Exam Answer Key

GRADE 9 SCIENCE

Final Practice Exam
Answer Key

Name: ______________________________

Student Number: ______________________

Attending ☐ Non-Attending ☐

Phone Number: _______________________

Address: ____________________________

____

____

For Marker's Use Only

Date: ______________________

Final Mark ______ /100 = ________%

Comments:

Instructions

- You have a maximum of 2 hours to write this exam.
- Supplies required: calculator, paper, and ruler

Multiple Choice

Each question has a single best answer. Make your choice by circling the letter beside your answer. **(*18 x 1 mark each = 18 marks*)**

1. In Western history, the first recorded scientist to propose that Earth revolved around the Sun was
   a. Galileo
   b. Copernicus
   c. Ptolemy
   d. Aristarchus
2. Sperm and egg cells are referred to as
   a. gametes
   b. zygotes
   c. diploid cells
   d. homologous cells

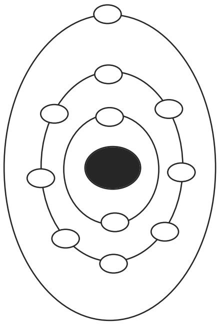
3. Which of the following elements has a total of six electrons in its valence shell?
   - a. nickel
   - b. chromium
   - **c. sulphur**
   - d. bromine
4. Jupiter, Saturn, Neptune, and Uranus are considered a family known as
   - a. the galactic planets
   - **b. gas giant planets**
   - c. terrestrial planets
   - d. solar planets
5. What is the azimuth of Polaris when observed from Winnipeg, Manitoba?
   - **a. 0°**
   - b. 15°
   - c. 35°
   - d. 50°
6. An example of a naturally occurring diatomic molecule is
   - a. gold
   - b. copernicium
   - c. carbon dioxide
   - **d. hydrogen gas**
7. Twelve coulombs of electric charge travels through a resistor which uses 24 joules of energy. What is the potential difference across the resistor?
   - **a. 2 J/C**
   - b. 12 J/C
   - c. 36 J/C
   - d. 288 J/C
8. Ernest Rutherford is credited for the discovery of
   - a. the moons of Jupiter
   - **b. the nucleus of the atom**
   - c. deoxyribonucleic acid (DNA)
   - d. the piezoelectric effect

Name: ____

9. Human egg cells are produced in the
   a. ovaries
   b. vagina
   c. cervix
   d. uterus

10. The unit for measuring electric current is the
    a. joule
    b. ohm
    c. ampere
    d. tesla

11. The diagram below represents



    a. an atom of magnesium
    b. a molecule of sodium
    c. an alkali metal
    d. a chalcogen

12. How long does it take the Moon to revolve around Earth?
    a. 24 hours
    b. 27 days
    c. 12 days
    d. 1 week

13. A mother is homozygous recessive for a sex-linked trait. Which statement is true?
    a. Half of her daughters will display the dominant phenotype.
    b. All of her daughters will display the recessive phenotype.
    c. All of her sons will display the dominant phenotype.
    d. All of her sons will display the recessive phenotype.

14. Stars such as our Sun produce their energy
    a. through the nuclear fission of helium into hydrogen
    b. through the nuclear fusion of hydrogen into helium
    c. through the nuclear fission of hydrogen into helium
    d. through the combustion of hydrocarbons

15. A diploid human cell contains
    a. 64 chromosomes
    b. 23 pairs of chromosomes
    c. 46 pairs of chromosomes
    d. 23 chromosomes

16. A rod that has been negatively charged touches an electroscope.
    a. Negative charges move out of the electroscope.
    b. Positive charges move out of the electroscope.
    c. Negative charges move into the electroscope.
    d. Positive charges move into the electroscope.

17. A metal that can be hammered into thin sheets demonstrates the property called
    a. malleability
    b. conductivity
    c. ductility
    d. lustre

18. Which scientist contributed to the first periodic table?
    a. Tycho Brahe
    b. Dimitri Mendeleev
    c. Aristotle
    d. Isaac Newton

Name: ____

Matching

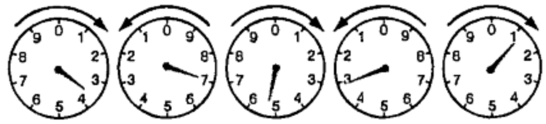
Place a letter in the pace provided that gives the best match.
(*18 x 0.5 marks each = 9 marks*)

f	insulator	a. discovered the moons of Jupiter
q	astrolabe	b. contain genes
c	Bohr	c. developed a model of electron orbitals
b	chromosome	d. the protons in a nucleus
e	halogen	e. chlorine
a	Galileo	f. does not conduct electricity
k	Punnett square	g. provides only one path for electrical current
i	light year	h. a vertical coordinate
g	series circuit	i. the distance that light travels in 365 Earth days
d	atomic number	j. the movement of electrons through a conductor
j	current	k. a model for predicting genotypes
m	neutron	l. female gonad
r	joule	m. found in the nucleus of an atom
n	potassium	n. an alkali metal
o	electroscope	o. detects electric charge
h	altitude	p. claimed that Earth orbited the Sun
l	ovaries	q. Arabic instrument for observing stars
p	Copernicus	r. unit of energy

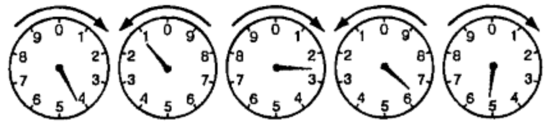
Short Answer (*29 marks*)

1. There are two hydro meter readings shown below. One meter reading is for July and the other is for August. (*4 marks*)

July:



August:



   a. What is the energy reading for July and August? Show the units. (*2 marks*)

   July = 37,531 kWh

   August = 41,265 kWh

   b. What is the energy consumption between July and August in this example? (*1 mark*)

   3,734 kWh

   c. If the cost for energy were $0.24 per kilowatt hour, what will this household pay for energy? (*1 mark*)

   The household would pay $896.16 for the energy.

2. Name two types of asexual reproduction. For each type, name one species that uses the method. (*4 marks*)

   Vegetative propagation → apple tree

   Binary fission → bacteria

   Regeneration → starfish, grass

   Sporulation → fungus, mushrooms, mold

   Budding → yeast

3. Identify the following elements by name and symbol. (*5 marks*)

   a. This element is the lightest in existence. **Hydrogen (H)**

   b. This element is the most reactive non-metal. **Fluorine (F)**

   c. The atomic mass of this element is approximately 32. **Sulphur (S)**

   d. This element contains two more protons than nickel. **Zinc (Zn)**

   e. On the periodic table, this element is located on the fourth period and the second family. **Calcium (Ca)**

4. What is a phenotype? How is it different from a genotype? (*3 marks*)

   A phenotype is an inherited characteristic that can be seen, such as physical appearance, behaviours, and functions. A genotype is the set of genes that determine a characteristic. Genotypes determine traits; phenotypes are the display of traits.

5. What is a geosynchronous orbit, and how does it benefit telecommunications systems? (*2 marks*)

   A geosynchronous orbit refers to an object that rotates around Earth at the same speed as the planet. This is useful in telecommunications because a satellite launched into geosynchronous orbit will maintain an exact position above the planet, allowing satellite dishes on the ground to receive constant information. Because the satellite is always in the same position, it is unnecessary to track it.

6. What is a nebula, and how does it form a star? (*3 marks*)

   A nebula is a cloud of gases and dust that swirl around in space. When this cloud of dust and gas gathers into a large clump, it increases the magnitude of its gravitational force. Once enough gas has bunched together under enough pressure, a fusion reaction begins, creating a star.

7. Fill in the blanks in the following sentences about cell division. (*5 marks*)

   Mitosis takes place in **somatic** cells, while meiosis occurs in **reproductive** cells. Mitosis produces two **diploid** cells, while meiosis produces a total of **4** cells, each with a **haploid** chromosome count.

8. Use the Energuide symbol below to answer the following questions. (*3 marks*)

   a. How much energy would be used by this appliance in a typical month of use?

      The appliance uses 123 kWh of electricity per month, on average.

b. If you were paying 7.5 cents per kWh for electrical energy in your area, what would it cost to use this appliance for three months?

Cost/month = kWh x (cost per kWh)

Cost/month = 123 kWh x $0.075

Cost/month = $9.225 → $9.23

Cost/month x 3 months = $9.23 x 3 = $27.69

It would cost $27.69 to use the appliance for three months.

Diagrams and Long Answers (*44 marks*)

1. In a species of dog, the gene for long hair (H) is dominant over the gene for short hair (h). A licensed breeder mates a long-haired male (Hh) with a long-haired female (Hh). (*7 marks*)

a. Draw a Punnett square showing the potential genotypes of this pairing's offspring. (*1 mark*)

	Father		
Mother		**H**	**h**
	H	**HH**	**Hh**
	h	**Hh**	**hh**

b. What are the possible genotypes of the offspring? In what percentages are they predicted to appear? (*3 marks*)

Twenty-five percent of the puppies will be homozygous dominant (HH).

Fifty percent of the puppies will be heterozygous (Hh).

Twenty-five percent of the puppies will be homozygous recessive (hh).

c. What phenotypes will the puppies display, and in what percentage? (*2 marks*)

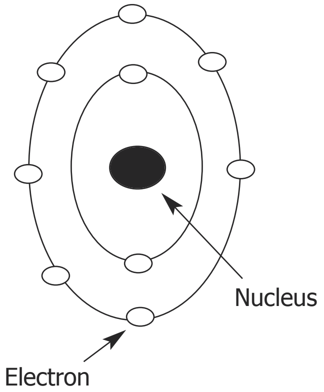
Seventy-five percent of the puppies are expected to show the long hair phenotype and 25 percent are expected to show the short hair phenotype.

d. How can the breeder alter the pairing to ensure that only long-haired puppies are born? (*1 mark*)

The breeder must ensure that at least one of the parents is homozygous dominant (HH) for the hair gene.

Name: ____

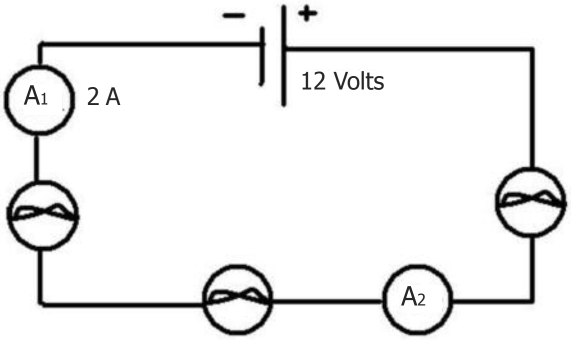
2. Draw a Bohr atom of fluorine. (*6 marks*)
   a. Draw the atom, labelling the nucleus and one of the electrons. (*2 marks*)



   b. How many neutrons are there in fluorine? (*1 mark*) **10 neutrons**
   c. What is the mass number for fluorine? (*1 mark*) **19 amu**
   d. To what family does fluorine belong? (*1 mark*) **halogen family**
   e. What is one trait shared by this family? (*1 mark*)

   Any one of the following:
   - **extremely reactive**
   - **always one electron short of a complete valence shell**
   - **all non-metals**

3. Use the diagram below to answer the following questions. (*5 marks*)

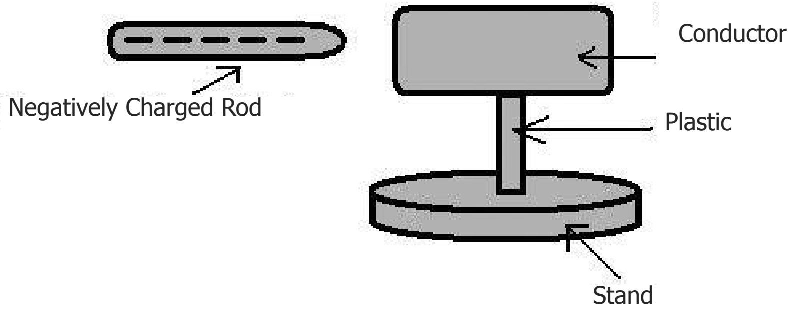


   a. Are the three bulbs connected in series or parallel? **Series**
   b. What is the reading in A2? **2 A**
   c. What is the total current in the circuit? **2A**
   d. The three light bulbs all have the same resistance. What is the voltage across each of the light bulbs? **4 volts**

e. Draw an arrow on the diagram indicating the direction of electron flow.

   The arrow should point away from the negative terminal of the battery and towards the positive terminal.

4. Use the diagram below to answer the following questions. (*5 marks*)



   a. Draw the charge distribution for the conditions shown on the conductor. (*2 marks*)

   Positive charges should be gathered to the left side of the conductor, nearest the negatively charged rod. Negative charges should be gathered to the right side of the conductor, farthest from the negatively charged rod.

   b. How would you give the conductor a permanent charge without moving the charged rod? (*1 mark*)

   I would ground the conductor.

   c. What charge would be left on the conductor after completing part (b)? (*1 mark*)

   A positive charge would be left.

   d. What name is given to this method of charging an object? (*1 mark*)

   This method of charging a conductor is called induction.

5. Describe how seasons are produced in the Northern Hemisphere. (*4 marks*)

   - **Earth revolves around the sun; has a tilted axis of rotation.**
   - **As the “tilted” Earth revolves around the Sun, one hemisphere will be angled towards the Sun, while the other is angled away.**
   - **When the Northern Hemisphere is angled towards the Sun, the Northern Hemisphere experiences an increased number of daylight hours, and enters summer.**
   - **When the Northern Hemisphere is angled away from the Sun, the Northern Hemisphere experiences few hours of daylight, and enters winter.**

Name: ____

6. Why are you unlikely to find snow in countries along the equator? (*2 marks*)

   The equator runs along the centre of Earth and is always angled towards the Sun. This region of Earth experiences roughly the same number of daylight hours throughout the year, so the temperature never drops low enough to freeze water.

7. What is the purpose of mitosis and meiosis within the human body? (*2 marks*)

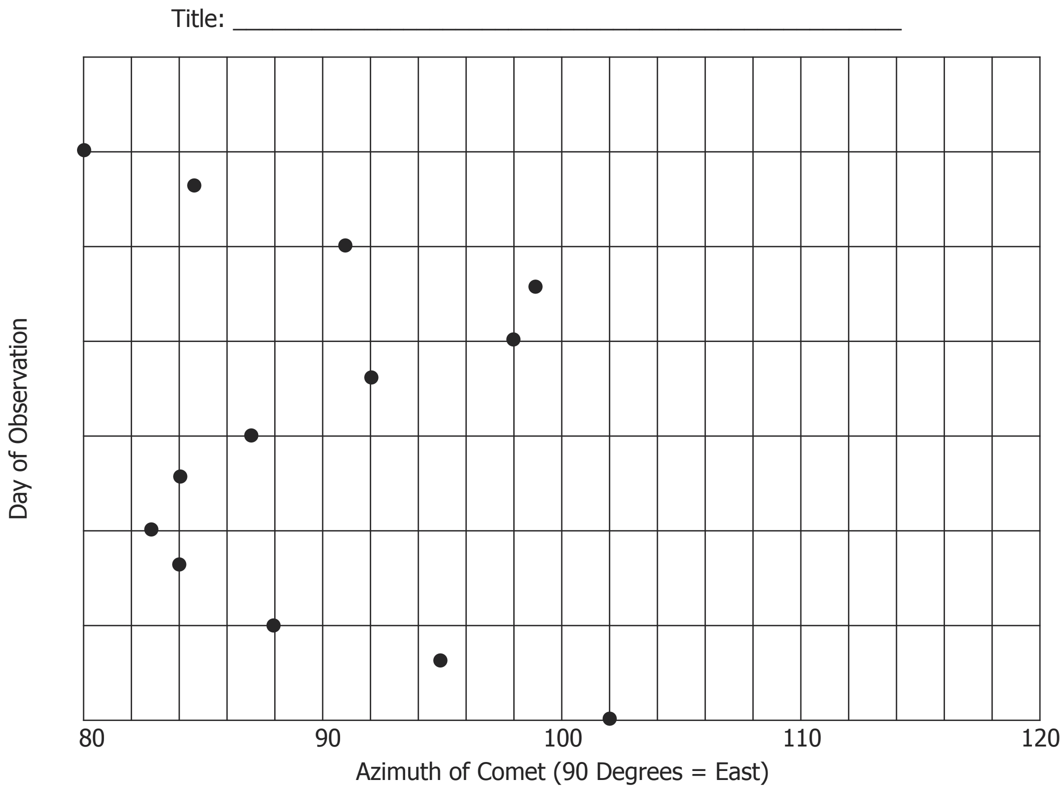
   Humans use mitosis in order to create identical copies of cells for the purposes of growth and repair.

   Humans use meiosis to produce gametes specifically for reproduction.

8. Darren has been observing a newly discovered comet through his telescope. (*8 marks*)

   a. Using the data provided in the table below, plot a graph showing the position of this new comet over the months of April to October. (*5 marks – 1 mark for title, 4 marks for graph*)

Observation Date	Comet Azimuth	Day within Study
April 1	102.0	0
April 15	95.0	15
May 1	88.0	30
May 15	84.0	45
May 30	83.0	60
June 14	84.0	75
June 29	87.0	90
July 14	92.0	105
July 29	98.0	120
August 13	99.0	135
August 28	91.0	150
September 12	85.0	165
September 27	80.0	180



b. When Darren shows his data table to Karen, she exclaims that he must have made an error, because the comet is clearly changing the direction of its revolution around the Sun. How might Darren defend his observations? (*3 marks*)

What Darren observed was the phenomenon of retrograde motion. Comets further from the Sun move more slowly in their orbits compared with Earth. This allows Earth to complete a revolution around the Sun before the new comet. From the perspective of someone on Earth, this act of "lapping" the new comet will cause it to appear as though it is zig-zagging east and west through the night sky.

9. What are five indicators of a chemical change? (*5 marks*)

When a chemical change occurs, you can expect to note

- **a change in colour**
- **heat or light being given off**
- **the formation of bubbles (from escaping gas)**
- **the appearance of a solid (precipitate) in a liquid**
- **that the changes are irreversible**