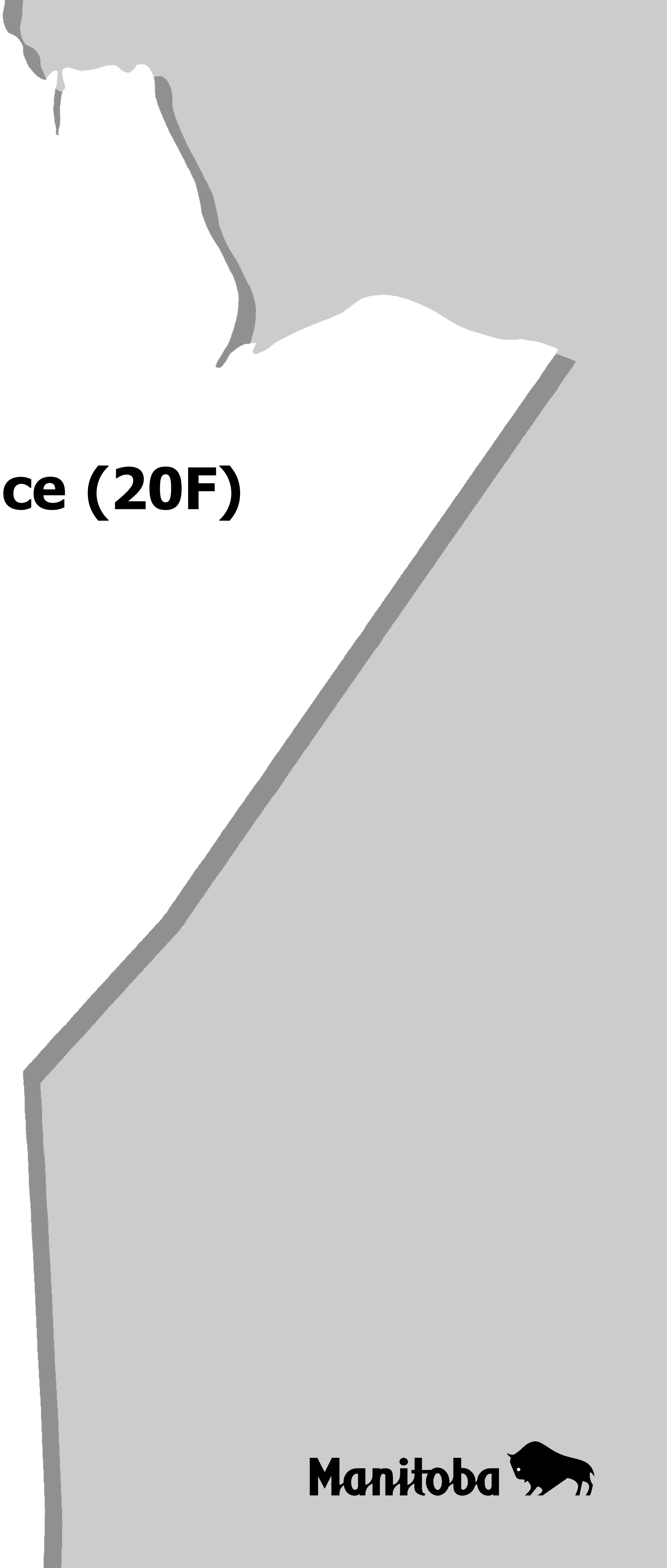
Grade 10 Science (20F)

A Course for
Independent Study



Manitoba

Grade 10 Science (20F)

A Course for Independent Study

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Manitoba Education
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Contents

Module 4: Weather Dynamics

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Grade 10 Science (20F)

Introduction

INTRODUCTION

Overview

Welcome to *Grade 10 Science: A Course for Independent Study*! This is a full-credit course that is designed to develop your scientific literacy through inquiry-based activities that aim to strengthen and encourage your critical thinking, problem solving, and analytical skills/abilities. The Grade 10 Science course is intended to provide a broad scientific background and to assist you in preparing for more specialized courses in Grade 11 and 12.

As a student enrolled in a distance learning 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 this course, *Grade 10 Science: A Course for Independent Study* students will learn about the fascinating world of ecosystems, how chemicals react, the physics of objects in motion, and how weather works, as well as how people can use their knowledge of ecology, chemistry, physics, and meteorology to live responsibly in our world.

How Is This Course Organized?

This course consists of the following four modules:

- Module 1: Dynamics of Ecosystems
- Module 2: Chemistry in Action
- Module 3: In Motion
- Module 4: Weather Dynamics

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

- **Lesson Focus:** The Lesson Focus at the beginning of each lesson identifies one or more specific learning outcomes (SLOs) that are addressed in the lesson. The SLOs identify the knowledge and skills you should have achieved by the end of the lesson.

- **Introduction:** Each lesson begins with an explanation of what you will be learning in that lesson.
- **Lesson:** The main body of the lesson is made up of the content that you need to learn. It contains text, explanations, images, and diagrams.
- **Learning Activities:** Many lessons include one or more learning activities that will help you learn about the lesson topics and prepare you for the assignments, the midterm examination, and the final examination. Once you complete a learning activity, check your responses against those provided in the Learning Activity Answer Key found at the end of each module. You will not submit the completed learning activities to the Distance Learning Unit.
- **Assignments:** Assignments are found at the end of lessons. You will submit your completed assignments to the Distance Learning Unit either by mail or electronically through the learning management system (LMS) at the end of each module. In total, all assignments are worth 60 percent of your final course mark.
- **Video Files:** Some lessons refer to the *Grade 10 Science Independent Study Video Files*, which you are required to view for this course.
- **Key Words:** This list identifies the important words that are used in the lesson. The key words are highlighted in bold within the text and identified by key word icons.
- **Summary:** Each lesson ends with a brief review of what you just learned.

This course also includes the following section:

- **Bibliography:** This list identifies the resources used to write this course.

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 and in the video files. You will, however, need access to a variety of resources.

The required and optional resources for this course are as follows:

Required Resources

For this course, you will need access to the following resources. If you do not have access to one or more of these resources, contact your tutor/marker.

- **Supplies:** A metric ruler, pencil, and coloured pencils (red, green, light blue, light brown)

- **Videos:** You will need to view the Grade 10 Science videos, which are available in the learning management system (LMS). If you do not have access to the Internet, or if you need a copy of the videos, contact the Distance Learning Unit at 1-800-465-9915.
- **Booklet:** You will need to read the booklet *In Motion: A Learning Resource for Students,* which 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 *In Motion: A Learning Resource for Students* booklet.
- **A computer/mobile device** to view video and PDF files: Access to a computer/mobile device with appropriate software is required to view the Grade 10 Science video files and the PDF file of the booklet *In Motion: A Learning Resource for Students.*

Optional Resources

It would be helpful if you had access to the following resources:

- **A calculator:** A calculator would be helpful as you work through the course. You may also use a calculator during the examinations.
- **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.
- Access to a **school laboratory** or access to **equipment** is required to perform **optional** laboratory activities. (You must be supervised by a teacher or guardian/parent.)
- **Resource people:** Access to local resource people, such as teachers, school counsellors, and librarians, would help you complete the course.
- **A computer with word processing and presentation software:** Access to word processing software (e.g., Microsoft Word) and presentation and slide software (e.g., Microsoft PowerPoint) would help you complete some assignments.

- **A computer/mobile device 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 Safety

If you choose to use the Internet to do research, be safe. The Internet is a valuable source of information and should be used responsibly. Talk to your parents/guardians about Internet safety, and use the following guidelines when going online:

- Choose a user name that does not reveal your name, gender, age, or other personal details.
- Never give anyone private information.
- Do not answer emails from strangers.
- If someone asks you to keep your relationship with him or her a secret, stop talking to the person and immediately tell your parent/guardian.
- Do not email or post pictures or files.

The above is **not** a complete list because no list can possibly cover all dangerous situations. Use your common sense and be careful.

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).

* **A note about Internet sites:** All of the URLs in the 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.

Your Learning Partner

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 examinations 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 a big deal with serious consequences, so it's important that you understand what it is and how to avoid it.

What is plagiarism?

In brief, plagiarism is taking someone's ideas or words and presenting them as if they are your own.

How can you avoid plagiarism?

- Begin early. Research takes time. Allow enough time to search for, evaluate, and read sources, and to get help if you need it. Always document your sources immediately.
- Present your research by quoting and paraphrasing.
  - When you use a quote, you use the exact same words with quotation marks, and you indicate exactly where it came from.
  - When you paraphrase, you rewrite an author's idea using your own words and you do not use quotation marks (but you also make sure to state clearly whose idea it is).
- Learn how to use different citation styles.
- Give credit where credit is due. Never pretend someone else's idea is your own.

How Will You Know How Well 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.

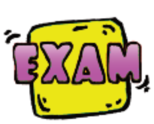
Make sure you complete the learning activities. Doing so will not only help you to practise what you have learned, but will also prepare you to complete your assignments and the examinations successfully. Many of the questions on the examinations will be similar to the questions in the learning activities.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

Assignments

Each module in this course contains assignments, which you will complete and submit to the Distance Learning Unit either by mail or electonically through the learning management system (LMS). The staff will forward your work to your tutor/marker. The assignments are worth a total of 60 percent of your final course mark.

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 examinations.

Midterm and Final Examinations



This course contains a midterm examination and a final examination.

- The **midterm examination** is based on Modules 1 and 2, and is worth 20 percent of your final mark in this course. You will write the midterm examination when you have completed Module 2.
- The **final examination** is based on Modules 3 and 4, and is worth 20 percent of your final mark in this course. You will write the final examination when you have completed Module 4.

The two examinations are worth a total of 40 percent of your final course mark. You will write both examinations under supervision.

To do well on each examination, you should review all the work you have completed from the modules, including all learning activities and assignments.

Practice Examinations and Answer Keys

To help you succeed in your examinations, you will have an opportunity to complete a Practice Midterm Examination and a Practice Final Examination. These examinations, along with the answer keys, are 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 examinations.

These practice examinations are similar to the actual examinations you will be writing. The answer keys enable you to check your answers. This will give you the confidence you need to do well on your examinations.

Requesting Your Examinations

You are responsible for making arrangements to have the examinations sent to your proctor from the Distance Learning Unit. Please make arrangements before you finish Module 2 to write the midterm examination. Likewise, you should begin arranging for your final examination before you finish Module 4.

To write your examinations, 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 complete 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 this 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 the 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	Middle of November
Midterm Examination	End of November
Module 3	Middle of December
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	Middle of February
Module 2	Beginning of March
Midterm Examination	Middle 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	Middle of October
Module 2	End of December
Midterm Examination	Middle of January
Module 3	Middle of March
Module 4	Beginning of May
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.

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 assignments you will be submitting at the end of each module.

Submission of Assignments	
Submission	Assignments You Will Submit
1	**Module 1: Dynamics of Ecosystems** Module 1 Cover Sheet Assignment 1.1: Biochemical Cycles Assignment 1.2: Toxin Investigation Assignment 1.3: Predator-Prey Interactions Assignment 1.4: Hydroelectric Power Decisions
2	**Module 2: Chemistry in Action** Module 2 Cover Sheet Assignment 2.1: Atoms and Ionic Compounds Assignment 2.2: Atomic Bonding Assignment 2.3: Conservation of Mass Assignment 2.4: Chemical Reactions Assignment 2.5: Acids and Bases Assignment 2.6: Chemistry in Technology and the Environment
3	**Module 3: In Motion** Module 3 Cover Sheet Assignment 3.1: Inertia and the Unrestrained Passenger Assignment 3.2: The Link between Force and Motion Assignment 3.3: Speed and Braking Distance
4	**Module 4: Weather Dynamics** Module 4 Cover Sheet Assignment 4.1: Energy Flow Assignment 4.2: Research Project Assignment 4.3: Climate Change Discussion

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: This graphic appears at the beginning of each lesson, indicating the specific learning outcomes targeted for the lesson.

Key Words: This graphic also appears at the beginning of each lesson, where there is a list of new words and terms that will be defined within the lesson.

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

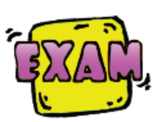
Learning Activity: Complete this learning activity to help you review or practise what you have learned and to prepare for your assignments or examinations. You will not send learning activities to the Distance Learning Unit.

Check Your Work: This graphic reminds you to check your work using the answer key.

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

Caution: Be careful when conducting this learning activity or experiment.

Submit Assignment: It is now time to submit your assignment for assessment. You will be sending in your assignments at the end of every module.



Examination: Write your midterm or final examination at this time.

Video: View a video.

Laboratory Activity: Complete an experiement at this time.

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 the course!

Grade 10 Science (20F)

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: Biochemical Cycles	______ /7	______ /7
❑ Assignment 1.2: Toxin Investigation	______ /14	______ /14
❑ Assignment 1.3: Predator-Prey Interactions	______ /14	______ /14
❑ Assignment 1.4: Hydroelectric Power Decisions	______ /22	______ /22
	Total: ____ **/57**	**Total:** ____ **/57**

For Tutor/Marker Use
Remarks:

Assignment 1.2: Toxin Investigation Rubric			
Content	**Length and Style**	**Sources Used**	**Total**
7 marks	3 marks	4 marks	
■ Describe how humans use the substance. *(2 marks)* ■ Describe how the substance affects human and/or environmental health. *(3 marks)* ■ Explain how people can avoid or reduce exposure to the substance. *(2 marks)*	**Report:** At least 1 typewritten page, double-spaced, using a font no larger than 12. **PowerPoint:** At least 4 slides. Text is in a font and colour that is easy to read. Uses backgrounds, transitions, and pictures to enhance the presentation. **Poster:** On 8-1/2″ x 11″ paper. Clear title and subheadings. Text is organized into sections. Uses colour and pictures to capture attention.	Include a "Works Cited" page at the end of your report that details all of your research resources. **Books:** Include the title, author, and publisher. **Internet Resources:** Include the Page Name, Author, and URL. **Interviews:** Include the name of each person you interview as well as their occupation and place of work.	
			_____ /14

Grade 10 Science (20F)

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: Atoms and Ionic Compounds	____ /41	____ /41
❑ Assignment 2.2: Atomic Bonding	____ /31	____ /31
❑ Assignment 2.3: Conservation of Mass	____ /23	____ /23
❑ Assignment 2.4: Chemical Reactions	____ /35	____ /35
❑ Assignment 2.5: Acids and Bases	____ /16	____ /16
❑ Assignment 2.6: Chemistry in Technology and the Environment	____ /24	____ /24
	Total: ____ **/170**	**Total:** ____ **/170**

For Tutor/Marker Use
Remarks:

Grade 10 Science (20F)

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	**Attempt 1**	**Attempt 2**
Which of the following are completed and enclosed? Please check (✓) all applicable boxes below.	____________ Date Received	____________ Date Received
❑ Assignment 3.1: Inertia and the Unrestrained Passenger	______ /14	______ /14
❑ Assignment 3.2: The Link between Force and Motion	______ /27	______ /27
❑ Assignment 3.3: Speed and Braking Distance	______ /15	______ /15
	Total: ____ /56	**Total: ____ /56**

For Tutor/Marker Use
Remarks:

Grade 10 Science (20F)

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	**Attempt 1**	**Attempt 2**
Which of the following are completed and enclosed? Please check (✓) all applicable boxes below.	____________ Date Received	____________ Date Received
❑ Assignment 4.1: Energy Flow	______ /12	______ /12
❑ Assignment 4.2: Research Project	______ /20	______ /20
❑ Assignment 4.3: Climate Change Discussion	______ /20	______ /20
	Total: ____ **/52**	**Total:** ____ **/52**

For Tutor/Marker Use
Remarks:

<table>
<tr><th colspan="4">Assignment 4.2: Research Project Rubric</th></tr>
<tr><th>Content</th><th>Length and Style</th><th>Sources Used</th><th>Total</th></tr>
<tr><td>14 marks</td><td>3 marks</td><td>3 marks</td><td></td></tr>
<tr><td>▪ provides details of the event (name of the event, date, time, location) (2 marks)
▪ provides the timeline of event (3 marks)
▪ provides social, economic, and environmental impacts (6 marks)
▪ provides analysis of aftermath and lessons learned (3 marks)</td><td>Report: At least 1 typewritten page, double-spaced, using a font no larger than 12.
PowerPoint: At least 5 slides. Text is in a font and colour that is easy to read. Uses backgrounds, transitions, and pictures to enhance the presentation.
Poster: On 8-1/2” x 11” paper. Clear title and subheadings. Text is organized into sections. Uses colour and pictures to capture attention.</td><td>Include a “Works Cited” page at the end of your report that details all of your research resources.
Books: Include the title, author, and publisher.
Internet Resources: Include the Page Name, Author, and URL.
Interviews: Include the name of each person you interview as well as their occupation and place of work.</td><td></td></tr>
<tr><td colspan="3"></td><td>____ /20</td></tr>
</table>

GRADE 10 SCIENCE (20F)

Module 1

Dynamics of Ecosystems

This module contains the following:

Module 1: Introduction

Welcome to Module 1: Dynamics of Ecosystems. This module will give you the chance to learn about the fascinating world of ecosystems. An ecosystem is a community of living organisms and the physical environment with which they interact. This topic is very important today because ecosystems are being seriously threatened by human activity.

You will apply your knowledge by examining a case study. At the end of this module, you will use the decision-making model to propose a course of action regarding an important environmental issue.

Learning Activities

There are several learning activities placed throughout this module, which will help you to 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.

Assignments

When you have completed the assignments for Module 1, submit your completed 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.

Assessment Checklist

- ❑ Lesson 3 — Assignment 1.1: Biochemical Cycles
- ❑ Lesson 6 — Assignment 1.2: Toxin Investigation
- ❑ Lesson 10 — Assignment 1.3: Predator-Prey Interactions
- ❑ Lesson 14 — Assignment 1.4: Hydroelectric Power Decisions

These assignments will be worth a portion of the 60 percent of the total marks you will receive for assignments in this course.

What Will You Need?

In order to complete this module, you will need access to the following resources.

Required Resources

- **metric ruler, pencil,** and **two coloured pencils** of your choice to complete the graph in Assignment 1.3

Optional Resources

- **A computer with Internet access** would be beneficial throughout this course, especially to complete research assignments like Assignment 1.2. It would also help you to access additional information that is provided on websites that are listed throughout the course. All URLs listed in this course were working when this course was written. However, since some Internet sites change or disappear, you might find that some of these sites are no longer available or appropriate. If that happens, you could use a search engine (e.g., google.ca) to find the information that you are looking for.
- **A computer with a word processor like Microsoft Word** would be beneficial to help you complete assignments, including Assignment 1.2, where you will have the option of writing a report.
- **A computer with presentation and slide software like Microsoft PowerPoint** would be beneficial to help you complete assignments, including Assignment 1.2, where you will have the option of creating a slide presentation.
- **Access to a library**, such as a public library or school library, would be beneficial, especially if you do not have access to a computer with Internet access. Access to a library would help you complete research assignments like Assignment 1.2.

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the difference between ecology, ecologist, and ecosystem
- ❑ provide examples of abiotic and biotic factors
- ❑ explain the difference between habitat and niche
- ❑ describe the roles of producers, consumers, and decomposers

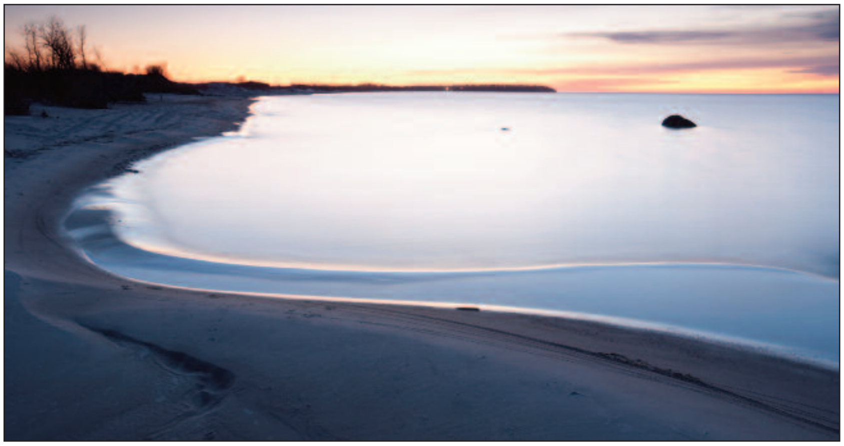
Key Words

- ecology
- ecologist
- ecosystem
- abiotic factors
- biotic factors
- produce
- consumer
- decomposer
- habitat
- niche

Introduction

Welcome to Grade 10 Science! This first lesson will re-introduce you to the field of ecology and to several key concepts that you may have covered in previous grades.

Setting the Scene



Dawn breaks over Lake Winnipeg. The early morning sunlight sparkles in the calm water. The plaintive call of a loon can be heard over a chorus of bullfrogs and red-winged blackbirds. A moose and her calf wade quietly in the muddy shallows, breakfasting on water lilies and pondweed. Jewel-like dragonflies chase mosquitoes along the water's edge as a snapping turtle suns itself on a rock. An eagle circles lazily overhead. Minnows dart in and out of wild rice in the shallows, while a northern pike lurks in the deeper water hoping for a meal. Two canoeists survey the scene and quietly remark that it is going to be a beautiful summer day.

All the living and non-living things described in this scene are involved in delicately balanced interactions with one another. How do wild rice, snapping turtles, mosquitoes, and the water of Lake Winnipeg interact?

Interactions among Living Things

The branch of biology that deals with the study of the interactions among organisms and with their environment is known as **ecology**. (The word *eco* comes from the Greek word *oikos*, which means house.) Scientists who study ecology are called **ecologists**. Because our planet has many diverse plants, animals, and environments, ecologists tend to study smaller areas called **ecosystems**. An ecosystem consists of the physical environment (**abiotic factors**) and all the living things (**biotic factors**) within it. Examples of abiotic factors in the physical environment include water, sunlight, oxygen, soil, nutrients, and temperature. Examples of biotic factors in an ecosystem include the plants, animals, fungi, and bacteria that live within it.

Each type of living thing in an ecosystem has a place in which it lives. This is known as its **habitat**. The combination of the job an organism does and the place in which it lives is called its **niche**. What are some jobs that organisms do? Plants and algae trap the energy in sunlight and produce their own food. Because of this, they are known as **producers**. Animals are **consumers** since they cannot make their own food and must obtain their food from producers or other consumers. Bacteria and fungi are **decomposers**. They eat dead plant and animal remains and convert them into substances that can be reused. They are the recyclers of the ecosystem.

Learning Activity 1.1: Introduction to Ecology

Remember: You do not hand in Learning Activities.

1. Define *ecology*, *ecologists*, and *ecosystems*. How are they related to one another?
2. Consider the Lake Winnipeg ecosystem described in the introduction. Write a descriptive paragraph that illustrates a local ecosystem with which you are familiar. It could be a local park, your yard, a forest, or a pond. Be sure to include a variety of abiotic and biotic factors in your descriptive paragraph, as well interactions among them.
3. How does a niche differ from a habitat?
4. What would happen to an ecosystem if all the decomposers were destroyed?
5. One student argues that humans are producers because they produce their own food by growing crops and raising livestock. Do you agree? Why or why not?

Check the Learning Activity Answer Key found at the end of this module.

Summary

At first glance, an ecosystem may appear simple, even boring. Upon closer examination, you will notice the wide variety of living things present in the ecosystem. Abiotic factors become apparent, as do the interactions of organisms with one another, and with the physical environment. Ecology truly is the study of the "houses" of Earth.

Notes

Lesson 2: Energy Flow

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe the roles of herbivores, carnivores, and scavengers
- ❑ explain the difference between a food chain and a food web
- ❑ draw a food web found in a local ecosystem
- ❑ describe how energy flows through an ecosystem
- ❑ describe two types of ecological pyramids

Key Words

- food chain
- food web
- pyramid of energy
- pyramid of biomass
- trophic level
- herbivore
- carnivore
- scavenger
- omnivore
- primary consumer
- secondary consumer
- tertiary consumer
- ecological pyramid

Introduction

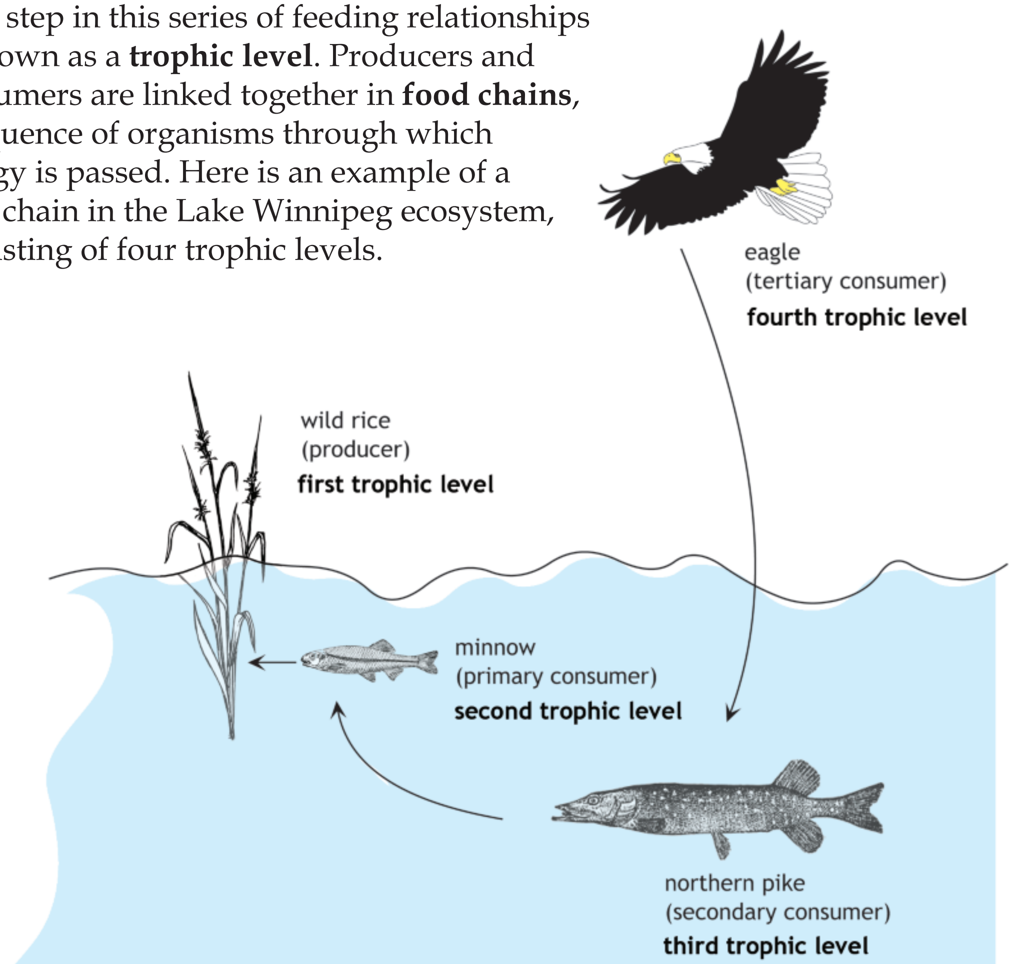
Now that you have familiarized yourself with ecosystems, this lesson will complete the review of prior concepts by investigating food chains and the predator-prey relationships that exist in all ecosystems.

Food Chains

Take a closer look at the interactions among organisms in an ecosystem. Since all living things require energy to live, the ultimate source of that energy is the Sun. Producers, such as plants and algae, capture the Sun's energy and use it to build plant parts and store extra energy in roots and seeds.

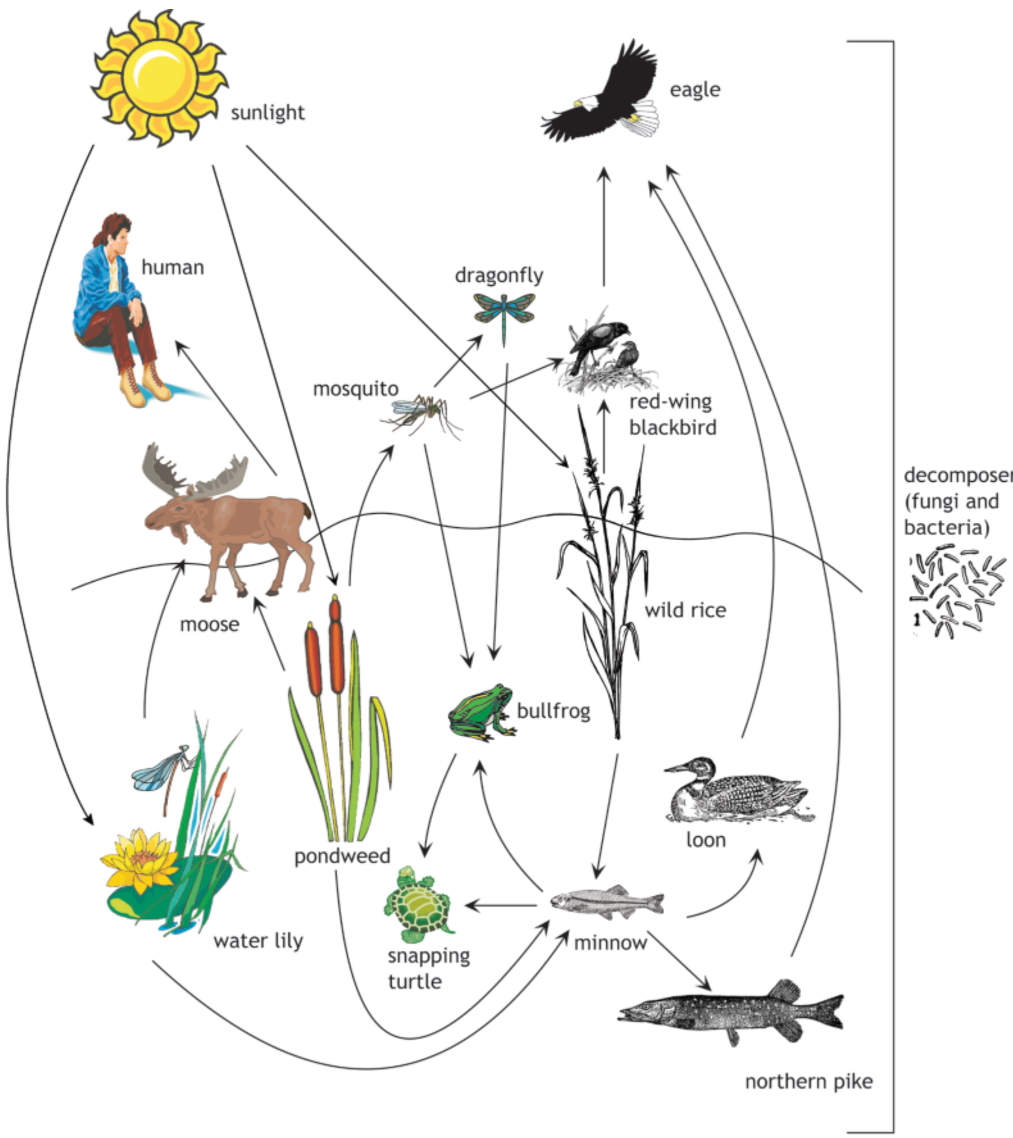
Unlike producers, consumers are unable to use sunlight as an energy source. **Primary consumers** (also called **herbivores**) feed directly on plants. Examples of herbivores include moose, cattle, and grasshoppers. **Secondary consumers** feed on primary consumers, and **tertiary consumers** feed on secondary consumers. Consumers above primary are also known as **carnivores**. Examples of carnivores include wolves, northern pike, and ladybugs. **Scavengers** are carnivores that feed on dead animals. Examples of scavengers include blowflies, turkey vultures, and ravens. We humans, along with black bears and red-winged blackbirds, are **omnivores** because we feed on both producers and consumers.

Each step in this series of feeding relationships is known as a **trophic level**. Producers and consumers are linked together in **food chains**, a sequence of organisms through which energy is passed. Here is an example of a food chain in the Lake Winnipeg ecosystem, consisting of four trophic levels.



Food Webs

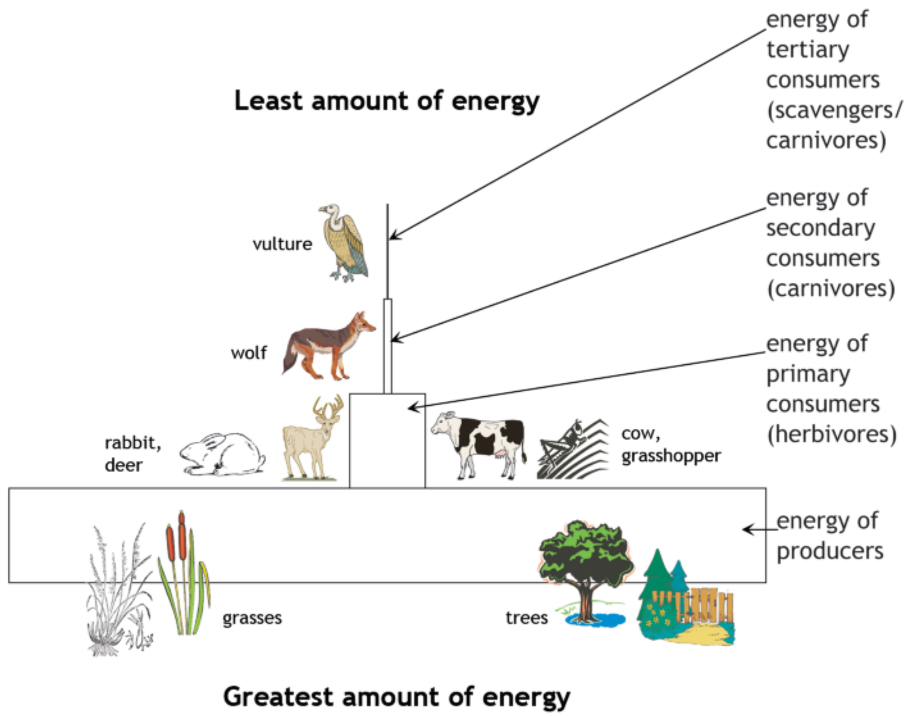
Because animals typically feed on more that one type of organism, food chains become connected in a complex relationship known as a **food web**. The diagram below shows the food web of the Lake Winnipeg ecosystem described in Lesson 1.



The arrows show how the Sun's energy flows through an ecosystem from the Sun, to producers, to consumers, and to decomposers. Because plants and animals die at all points in food chains, decomposers are found at all trophic levels in ecosystems.

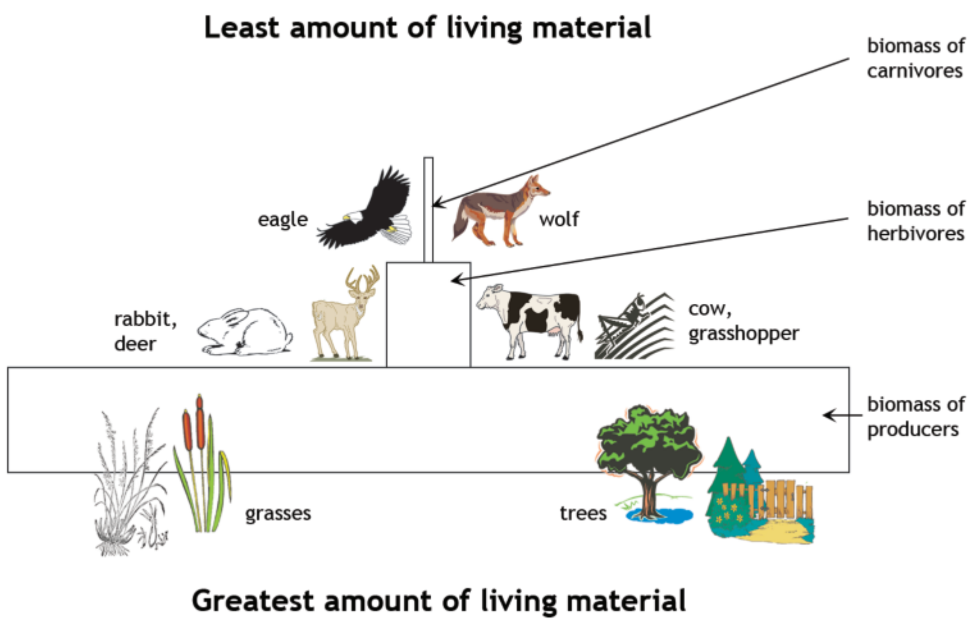
Ecological Pyramids

Ecologists use **ecological pyramids** to describe the energy flow among the trophic levels. The area at the bottom of the **pyramid of energy** represents the greatest amount of energy in an ecosystem. As the energy passes from producers to consumers, less is available at each successive trophic level.



This is because all the energy that an organism takes in is not transformed into food. Energy is used by the organism for a variety of life processes such as breathing, transporting materials, movement, reproduction, and so on. Less and less energy is available to organisms higher up the food chain. This explains why there are seldom more than four or five trophic levels in a food chain.

Related to the pyramid of energy is the **pyramid of biomass**. This pyramid shows the total amount of living material available at each trophic level. The area at the bottom of the biomass pyramid corresponds to the producer level. This represents the greatest amount of living material.



In an aquatic ecosystem, for example, it takes a large amount of producers (such as aquatic plants) to support a small number of herbivores (such as moose). The number of carnivores (such as wolves) that can be supported by the moose is even smaller yet.

In other words, there are more producers in an ecosystem than there are carnivores.

Learning Activity 1.2: Energy Flow

1. Why is it more energy-efficient for humans to eat grains and vegetables rather than meat?
2. Why is sunlight needed to maintain an ecosystem?
3. Complete the following chart.

Definition	**Term**	Example
	Herbivore	

Definition	**Term**	Example
	Carnivore	

Definition	**Term**	Example
	Scavenger	

Definition	**Term**	Example
	Omnivore	

Check the Learning Activity Answer Key found at the end of this module.

Summary

Food chains consist of producers and consumers, which are connected into food webs. Energy flows through ecosystems from one trophic level to the next. Pyramids of energy and biomass can be used to illustrate this energy flow.

A series of checks and balances regulates these complex relationships and maintains the stability of ecosystems. As you proceed through the lessons in this module, you will gain an understanding of how ecosystems are regulated, and what can happen to an ecosystem if the checks and balances are disrupted.

Notes

Lesson 3: The Cycles of Life

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain how carbon is cycled through an ecosystem
- ❑ explain how oxygen is cycled through an ecosystem
- ❑ explain how nitrogen is cycled through an ecosystem
- ❑ discuss the importance of nutrient cycling in ecosystems

Key Words

- carbon cycle
- oxygen cycle
- nitrogen cycle
- fossil fuels
- legume
- nitrogen fixation
- denitrification
- biogeochemical cycle
- combustion
- photosynthesis
- cellular respiration
- glucose
- nitrate

Introduction

If you have previously studied chemistry, you may be familiar with the law of conservation of mass. This states that, while matter may change its properties or state (such ice melting to water and then evaporating), there will always be a fixed amount of substance on Earth. This law accounts for how nutrients such as carbon, oxygen, and nitrogen will cycle through an ecosystem—changing form, but always remaining in the environment. In this lesson, you will learn exactly how these three substances move through an ecosystem.

Biogeochemical Cycles

Let's take a closer look at the interactions between living things and the physical environment in an ecosystem. While energy flows in a one-way direction through an ecosystem, nutrients are recycled over and over again. **Biogeochemical cycles** are the processes by which nutrients move through organisms and the environment. You may be familiar with the water cycle in which water moves from Earth's atmosphere to the surface (precipitation) and back to the atmosphere again (evaporation). Other important nutrients that are recycled are carbon, oxygen, and nitrogen.

Carbon and Oxygen Cycles

Since all living things on our planet are made up of molecules containing carbon, how carbon is cycled on the planet is an important process. Not only are the molecules of life built using carbon, the energy most of the living things on the planet need for life is the chemical energy of carbon-based molecules—primarily a sugar called glucose. Several natural processes are responsible for cycling carbon and, for most ecosystems, carbon and oxygen are closely linked.

In order to survive, all living things need energy. Energy is used to put atoms and molecules together to build cells and tissues, to break down complex molecules in food, and to allow an organism to move. The primary source of this energy for most ecosystems is the Sun. Producers such as green plants and algae use the Sun's energy to join carbon dioxide (CO_2) and water molecules (H_2O) using a process called **photosynthesis**. Photosynthesis is a complicated biochemical process involving many steps and many different enzymes (special protein chemicals) in cells. However, the end results of photosynthesis are glucose molecules (a type of sugar with the chemical formula $C_6H_{12}O_6$) and oxygen gas (O_2). The chemical bonds in glucose molecules are how a producer captures the Sun's energy. We can summarize the process of photosynthesis like this:

Photosynthesis
Sun's energy + carbon dioxide + water → glucose + oxygen

In chemical terms, we would write this summary like this:

Photosynthesis (chemical formula)
Energy + $6CO_2$ + $6H_2O$ → $C_6H_{12}O_6$ + $6O_2$

So this is how producers capture and store energy. This energy can now be used to run all the chemical reactions that plants need to grow and maintain themselves.

To use this stored energy, producers now reverse the process and breakdown the chemical bonds in glucose, releasing the energy. This is called **cellular respiration**. We can summarize cellular respiration by simply reversing the photosynthesis formula:

Cellular Respiration
glucose + oxygen → Sun's energy + carbon dioxide + water

Cellular Respiration (chemical formula)
$C_6H_{12}O_6$ + $6O_2$ → Energy + $6CO_2$ + $6H_2O$

Looking at the formula, we can see that an organism needs oxygen to break apart sugars.

Since photosynthesis and cellular respiration are the reverse of each other, we often write the summary with a double arrow in the middle like this:

$$\text{Energy} + 6CO_2 + 6H_2O \leftrightarrow C_6H_{12}O_6 + 6O_2$$

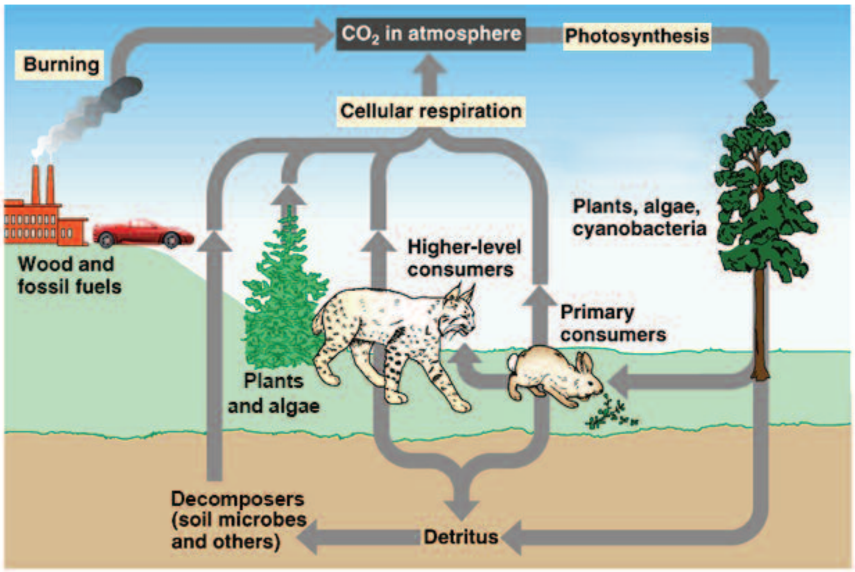
NOTE: Plants and other producers need oxygen for cellular respiration. It is a common misconception that plants release oxygen during the day and use oxygen at night. Plants use oxygen all the time. During the day they produce more oxygen than they use.

Primary consumers (herbivores) and secondary consumers (carnivores) cannot capture energy and carbon atoms like producers. Instead, they eat producers or other consumers, which contain glucose and the carbon atoms they need. The bodies of consumers use cellular respiration to release the energy from glucose. This is why consumers need oxygen to survive. Without it they cannot get energy from glucose.

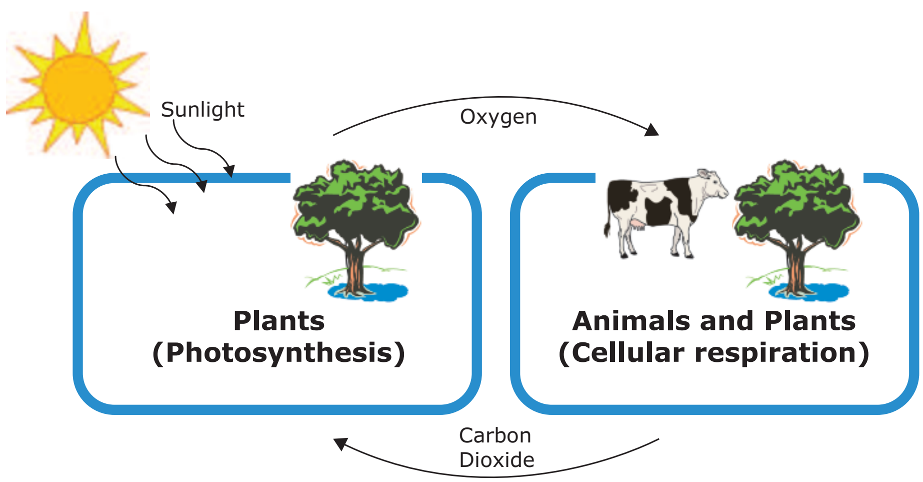
Another source of carbon is from burning carbon-containing molecules. The scientific term for burning is **combustion**. Forest and grass fires release carbon dioxide into the atmosphere. Fossil fuels (gasoline, coal, natural gas, etc.) are the remains of plants and animals that have been buried for millions of years. Humans burn fossil fuels in our vehicles and homes, also releasing carbon dioxide to our environment.

The carbon and oxygen cycles are summarized in the following diagrams.

The Carbon Cycle



The Oxygen Cycle



Nitrogen Cycle

Nitrogen is an important nutrient found in all living things and is used to build proteins.

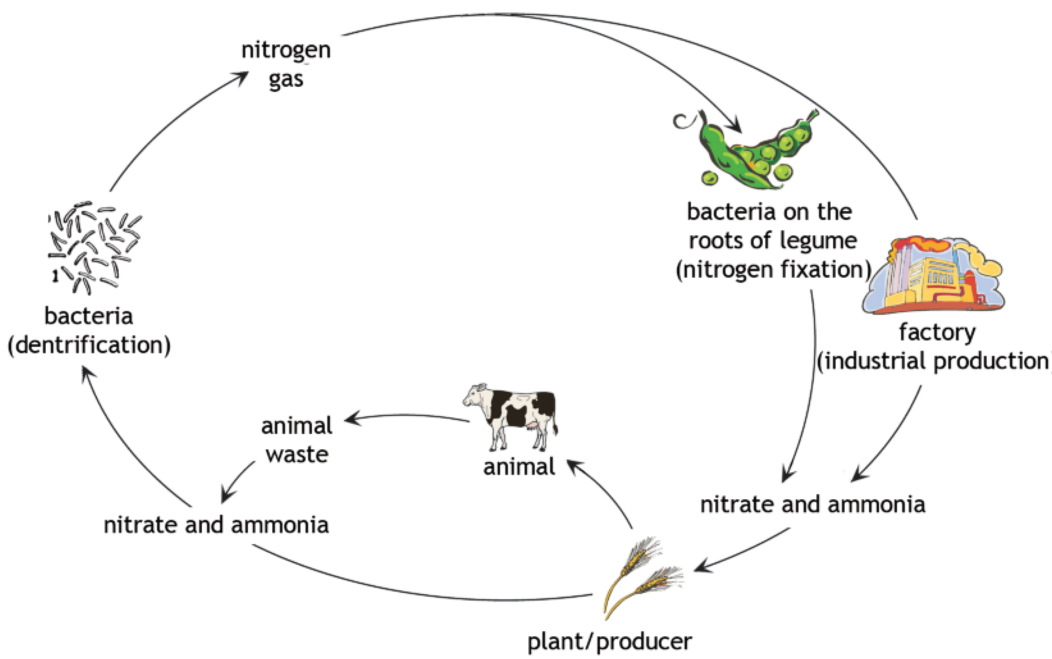
The process by which nitrogen moves through an ecosystem is known as the **nitrogen cycle**. While nitrogen gas makes up about 78 percent of Earth's atmosphere, most living things cannot use it in this gas form. The chemical formula for nitrogen gas is N_2.

Certain bacteria can change nitrogen gas into **nitrate** and **ammonia**. These are nitrogen compounds that plants can use. The process is known as **nitrogen fixation** and occurs in the roots of **legume** plants. Legumes include clover, alfalfa, beans, and peas. All plants then convert the nitrate and ammonia produced in the roots of legumes into a variety of plant proteins.

When animals eat plants, they convert plant protein into animal protein. For example, when you eat bread, beans, pasta, or any other foods containing plant matter, your body converts the protein into muscle, hair, fingernails, and other animal proteins. When you eat meat, your body also converts the animal proteins into the proteins your body needs.

When plants and animals die, decomposers break down their remains. Some bacteria and fungi cause proteins to decay into nitrate and ammonia, which can then be taken up again by plants and used to make proteins. Other bacteria will convert nitrate and ammonia back into nitrogen gas in a process known as **denitrification**. This process also occurs when bacteria convert animal waste (e.g., sewage) and plant waste (e.g., dead leaves) into nitrogen gas.

The diagram below illustrates the cycling of nitrogen in a farm ecosystem. Notice that the processes of nitrogen fixation and denitrification are required to maintain the cycle.



Chemists have created an industrial process that creates nitrates and ammonia in factories. This industrial nitrogen fixation produces fertilizer that farmers use to grow better crops.

Learning Activity 1.3: Comparing and Contrasting Processes

1. Complete the following Compare and Contrast frame for the terms *photosynthesis* and *cellular respiration*.

Compare and Contrast

Unit ______________________ Topic ______________________

C O M P A R E

How are photosynthesis and cellular respiration alike?

continued

Learning Activity 1.3 (continued)

C O N T R A S T

How are photosynthesis and cellular respiration different?

Write a statement to compare and contrast the two terms, concepts, or events.

Compare and Contrast Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Check the Learning Activity Answer Key found at the end of this module.

Summary

In this lesson, you have studied the carbon cycle, the oxygen cycle, and the nitrogen cycle. These biogeochemical cycles are the means by which nutrients move through organisms and the environment. These cycles allow nutrients to be recycled over and over again. In the next lesson, we will examine how ecosystems are affected when nutrient cycles are disturbed.

Notes

Assignment 1.1: Biochemical Cycles (7 marks)

1. Explain how the oxygen cycle and the carbon dioxide cycle work together. *(2 marks)*

2. Describe the relationship between nitrogen fixation and denitrification. *(2 marks)*

3. Why is nutrient cycling so important in ecosystems? *(3 marks)*

Notes

Lesson Focus

After completing this lesson, you will be able to

- ❑ list sources of carbon
- ❑ describe how natural events may disturb the carbon cycle
- ❑ describe how human activities may disturb the carbon cycle
- ❑ suggest ways in which we can reduce the flow of carbon dioxide into the atmosphere

Key Words

- cellulose
- fossil fuels
- combustion
- deforestation

Introduction

The carbon cycle involves more than a simple exchange of materials between photosynthesis and cellular respiration. There are many natural events that will forcibly move carbon through an ecosystem, typically causing it to gather in the atmosphere. In this lesson you will learn about these natural events, as well as some of the human activities that alter the carbon cycle.

Sources of Carbon

As you recall from the previous carbon cycle lesson, plants remove carbon dioxide from the atmosphere and use it to produce glucose in the process of photosynthesis. The glucose is then used by organisms and turned into carbon dioxide and energy in a process known as **cellular respiration**.

Plants and animals can convert glucose into other types of carbon compounds. For example, if we eat more food than we need to supply us with energy, our bodies change the glucose (and other nutrients) into fat. Plants convert glucose into starches and oils to store their excess energy. Plants also change glucose into cellulose, an important component of wood and other plant fibres.

Disturbing the Carbon Cycle: Natural Events

The cycling of carbon can be disturbed by natural events. Forest fires are one example. The **combustion** (or burning) of plant material, such as wood, releases large amounts of carbon dioxide into the atmosphere. Similarly, the burning of leaves and stubble in the fall increases the amount of carbon dioxide in the atmosphere.

Volcanoes can disrupt the cycling of carbon. Volcanic activity can break down rocks containing carbon compounds and release carbon dioxide into the atmosphere. The ash generated from a volcano can also block sunlight from reaching Earth's surface. This may reduce the amount of photosynthesis done by plants. This, in turn, could cause the amount of carbon dioxide in the atmosphere to increase.

Disturbing the Carbon Cycle: Human Activities

The cycling of carbon can be disturbed by human activities. **Deforestation** is the cutting down of forests. Forests are cleared to create more land for farming and to allow towns and cities to grow. Deforestation has reduced the amount of plants available for photosynthesis. Fewer plants mean that less carbon dioxide can be removed from the atmosphere.

When plants and animals die, their remains usually decay, and the carbon contained in them is released back into the atmosphere as carbon dioxide. On occasion, plant and animal remains break down very slowly. The carbon from the remains is stored in the earth and becomes fossil fuel. The **fossil fuels** (such as gasoline, coal, and natural gas) that we burn to produce energy also release carbon dioxide into Earth's atmosphere. The energy is then used to heat our homes and run our automobiles and factories.

The amount of carbon dioxide in our atmosphere has increased in the past 150 years because we use more fossil fuels. There is a concern that the increased amount of carbon dioxide in the atmosphere has lead to global warming. You will learn more about this topic in Module 4: Weather Dynamics.

What Can We Do?

How can we reduce the flow of carbon dioxide into the atmosphere? We can try to reduce the effects of deforestation by planting more trees and shrubs in our yards. We can also recycle paper and building materials so that fewer trees need to be cut down.

We can reduce our consumption of fossil fuels in our homes. This can be accomplished in many ways. We can turn down the thermostat in the winter. We can add insulation to the attic. Old windows and doors can be replaced with newer ones. By making our homes more energy-efficient, we can reduce the amount of home-heating oil and natural gas that we use, thereby decreasing the amount of carbon dioxide we produce.

We can reduce our consumption of fossil fuels used in transportation. Skateboarding, cycling, or walking to meet friends produces much less carbon dioxide than does driving an automobile. A large vehicle, such as an SUV, minivan, or pickup truck, is less energy-efficient than a subcompact or compact car. Large vehicles with large engines produce more carbon dioxide than do small cars with small engines.

Learning Activity 1.4: The Carbon Cycle

1. Explain how deforestation, fire, and combustion of fossil fuels disrupt the balance between photosynthesis and cellular respiration.
2. A slogan of the environmental movement is "Think globally. Act locally." How does this slogan apply to the increasing atmospheric carbon dioxide levels and to changing your lifestyle to help reverse this trend?
3. Why might it be difficult to change some of our actions that disturb the carbon cycle? Give specific examples.

Check the Learning Activity Answer Key found at the end of this module.

Summary

The carbon cycle is not always a balanced phenomenon. At times, large quantities of carbon will gather up at one station of the cycle due to phenomena such as volcanic eruptions or forest fires. Humans have the ability to intervene in the carbon cycle in ways that either add to these imbalances or minimize them.

Lesson 5: Disturbing the Nitrogen Cycle

Lesson Focus

After completing this lesson, you will be able to

- ❑ list sources of nitrates and ammonia
- ❑ describe the consequences of algal blooms
- ❑ explain how fertilizer and manure can enter bodies of water
- ❑ identify how human health can be affected by disturbed nitrogen cycling
- ❑ describe how human sewage and waste water can enter bodies of water

Key Words

- fertilizer
- algal bloom
- holding tank
- runoff
- septic field
- anemia
- waste water
- manure
- sewage
- water treatment plant

Introduction

The carbon cycle is not the only biochemical cycle that can run into an imbalance. Nitrogen-containing compounds can also become bottlenecked at certain points in the nitrogen cycle due to natural events and human activities. This lesson will explore these disturbances in the nitrogen cycle.

Sources of Nitrogen

As you recall from the nitrogen cycle lesson, nitrogen is fixed from the atmosphere into two major nitrogen-containing compounds—nitrate and ammonia. Plants use ammonia and nitrate to create plant proteins. Farmers will add **fertilizer** to their fields in the late spring, which contains nitrate and ammonia to improve plant growth. Nitrate and ammonia are also found in a wide variety of substances, including human sewage, pet and livestock feces (solid waste), lawn and garden fertilizers, eroded soil, industrial waste, and household waste water.

Nitrates, Ammonia, and Aquatic Ecosystems

Aquatic plants are an essential component of the aquatic food chain and their growth generally depends upon the availability of nitrate and ammonia. Too much of these nitrogen-containing compounds can lead to an overabundance of plants, which have harmful effects on lakes and rivers.

Bodies of water containing an excess of nitrates and ammonia have frequent **algal blooms** (growth of algae) and thick weedbeds along the shoreline. Algal blooms occur when sunlight, warm water, and excessive nutrients cause algae to grow rapidly. The blooms can produce dangerous toxins, which can harm fish and wildlife. Beaches in recreational areas are closed during algal blooms to prevent people from ingesting toxins when swimming. The toxins can also irritate the skin. Excessive algae in drinking water can affect its taste and odour. Drinking water or eating fish containing toxic algae can cause stomach upset and diarrhea.

Eventually the algal blooms "crash" and the algae begin to die. The decomposing weeds and algae deplete oxygen from the water. Fish kills or the death of many fish can occur due to a lack of oxygen, particularly in the winter.

Farm Runoff

The agricultural industry is a major source of the nitrate and ammonia entering Manitoba's lakes and rivers. Livestock operations such as cattle feedlots and hog and chicken barns produce large quantities of animal feces, also known as **manure**. The disposal of manure is monitored so that large amounts of manure are not washed off the land and into lakes and rivers during the spring snowmelt or heavy rainstorms as **runoff**.

The excessive use of fertilizers on cropland is a major concern. Soil may erode and fertilizers may wash off farmland during the spring snowmelt or in heavy rainstorms. This is how fertilizers come to be found in rivers and lakes.

The ammonia and nitrates can also seep into the ground and enter the groundwater. In rural areas, people obtain their drinking water from wells that tap into the groundwater. The ingestion of nitrates can cause in children a blood disorder called **methemoglobinemia**.

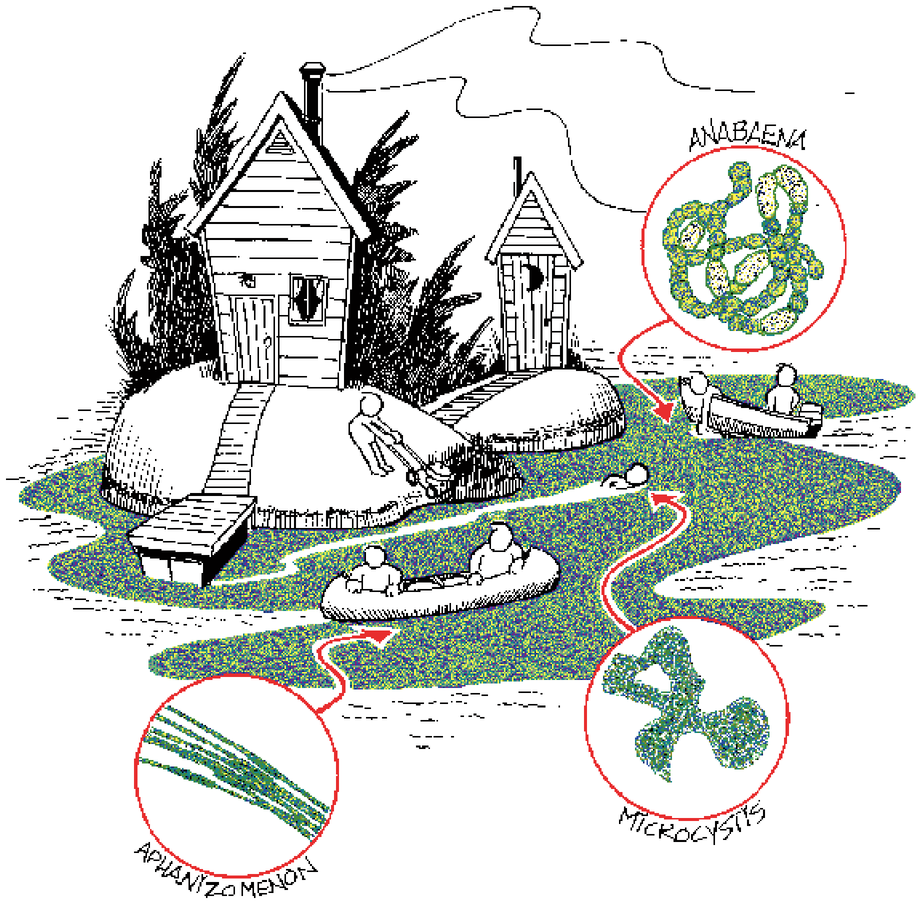
Human Sewage and Waste Water

In larger communities, **sewage** (human liquid and solid waste) and **waste water** (dirty water from sinks and showers) are collected in underground sewers. The waste is pumped to a **water treatment plant** where it undergoes several phases of treatment. When the water is mostly cleaned of the waste, the water is returned to a lake or river.

In small or rural communities, homes are connected to individual septic fields. A **septic field** consists of a buried tank into which waste water and sewage are pumped. The wastes are filtered through layers of gravel and are broken down by bacteria. The clean water then drains into the ground. Cottages usually have **holding tanks** that collect and store sewage and waste water. The holding tanks must be pumped out regularly, and the waste water and sewage transported to a treatment facility.

Occasionally, problems with waste water and sewage treatment occur. Septic fields and holding tanks may leak, releasing waste water and sewage into the ground. These materials can seep into the earth, enter groundwater, and end up in people's drinking water. Water treatment plants can malfunction, releasing raw sewage into lakes and rivers. A heavy rainstorm may overwhelm the capacity of a water treatment plant, requiring the release of partially treated waste water into a lake or river.

Figure 1.1 ***An algal bloom***



Source: Manitoba Conservation. "An Algal Explosion!" *The Manitoba Clean Water Guide*. Winnipeg, MB: Manitoba Conservation, n.d. Reproduced with permission.

What Can We Do?

Prevention is the best method for controlling the problem of excess nitrates and ammonia in our waters. We can help protect our water by ensuring our sewage and waste water do not enter lakes, rivers, and groundwater. For example, cottage outhouses with holding tanks should replace old-fashioned "pit" outhouses.

We can make certain that holding tanks and septic fields are operating properly. A leaking septic field or holding tank can cause nitrates and ammonia to enter surface water (lakes and rivers) and groundwater. Waste water should be disposed of properly and never dumped directly into lakes and rivers.

We can limit our use of fertilizers, especially near bodies of water. Heavy rains or lawn watering can wash fertilizers off the land into the water where algae will use them to grow. We can reduce soil erosion along shorelines by maintaining natural vegetation such as bulrushes and cattails.

Learning Activity 1.5: The Nitrogen Cycle

1. Predict the time of the year in which an algal bloom is most likely to occur. Explain the reasons for your prediction.
2. Describe ways in which human health can be affected by disturbed nitrogen cycling.
3. How can fertilizer and manure enter lakes and rivers?
4. Can you identify human activities that should not be taking place in waters in which an algal bloom is occurring?
5. Backcountry campers are advised to bury their feces in the ground and to avoid washing pots and dishes in the lakes and rivers. Why do you think this is so?

Check the Learning Activity Answer Key found at the end of this module.

Summary

As in the carbon cycle, nitrogen is prone to building up at inconvenient points along its cycle. Carbon (dioxide) becomes an issue when gathered in the atmosphere, but nitrogen-containing compounds are particularly hazardous when they accumulate in water systems. It is important to be aware of how our activities can disturb these natural cycles and of what actions we can take to reduce the impact of biochemical imbalances.

Notes

Lesson 6: Bioaccumulation

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the difference between biodegradable and non-biodegradable substances
- ❑ describe how bioaccumulation occurs
- ❑ explain the potential impact of bioaccumulation on consumers

Key Words

- bioaccumulation
- biomagnification
- biodegradable
- non-biodegradable
- toxin
- DDT
- mercury

Introduction

You have previously studied how nutrients containing carbon, oxygen, and nitrogen are cycled through ecosystems, as well as how the cycling of these nutrients can be disturbed. Now you will examine what happens when the cycling of some materials stops.

Biodegradable and Non-biodegradable Substances

As you recall from Lesson 2: Energy Flow, decomposers break down substances into the basic nutrients from which they were made. Substances that are broken down naturally in the environment are **biodegradable**. Examples of biodegradable substances include sewage, food scraps, and dead organisms. **Non-biodegradable** substances are broken down very slowly or not broken down at all by natural processes. Once these pollutants enter an ecosystem, they will remain there forever. Examples of non-biodegradable substances include **DDT** (a pesticide), mercury, glass, and certain types of plastics. A pollutant becomes a **toxin** when it adversely affects living organisms. Examples of toxins include DDT and mercury.

Bioaccumulation

What happens when non-biodegradable substances enter ecosystems? When producers such as plants and algae take in the water they require for photosynthesis, they may also absorb small amounts of non-biodegradable substances. Because these substances cannot be used or broken down, they are stored inside the plants. The toxins begin to accumulate inside the producers and become part of the food chain.

When herbivores eat the plants containing the non-biodegradable substances, they too begin to store the toxins in their fat. Because many producers must be eaten to keep one herbivore alive, the amount of toxin inside one herbivore is much higher than that of the individual producers it consumed. The stored toxins continue to be passed up the food chain, moving from primary to secondary to tertiary consumer. This process is known as **biomagnification** (or biological magnification or bioamplification).

At each trophic level, the amount of toxin inside the organisms increases, because each predator must eat many prey. This process is known as **bioaccumulation**. Eventually the levels of the toxin become high enough inside the secondary or tertiary consumers that their health is affected. They may be poisoned and die, or weakened and more susceptible to disease or predators.

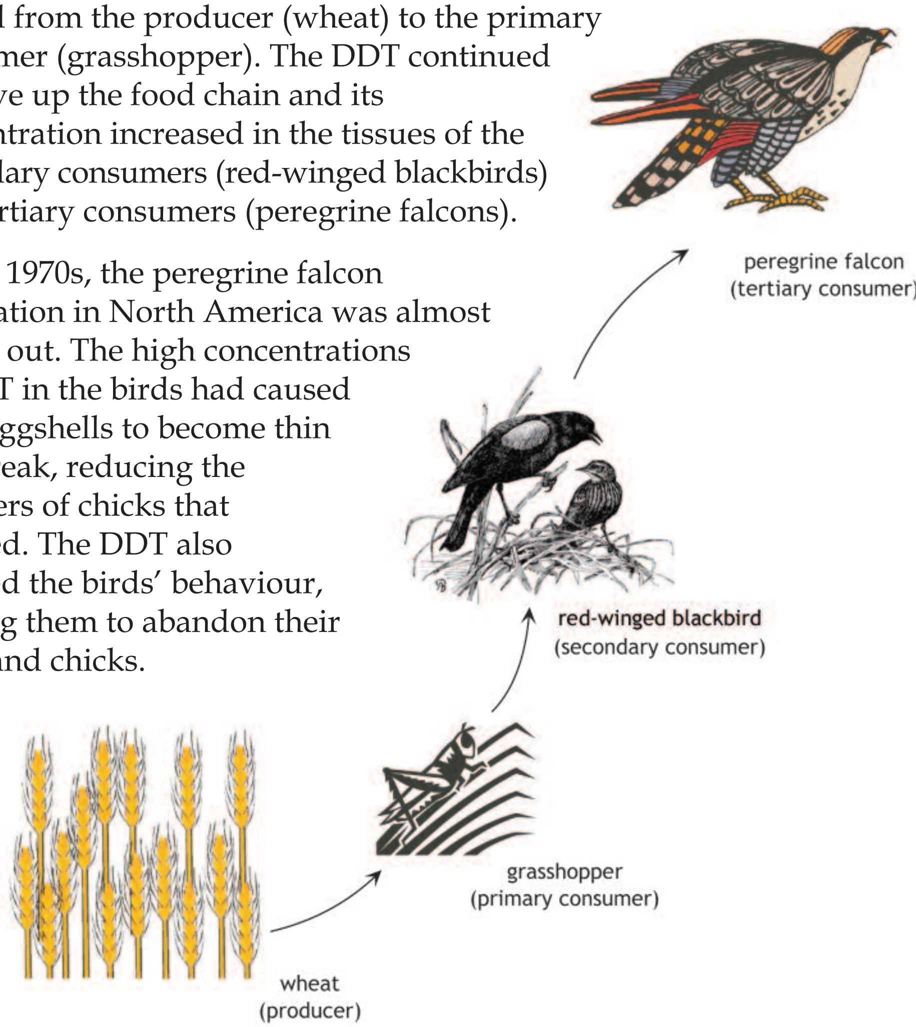
Example 1: DDT in Birds

One well-known example of bioaccumulation is that of the pesticide DDT. Starting in the 1940s, this chemical was sprayed on crops to control insects. In the 1950s and 1960s, the number of birds of prey such as peregrine falcons, hawks, and eagles began to decline rapidly.

Examine the food chain in the diagram below.

Wheat was sprayed with DDT to kill the insects that fed on it. When grasshoppers ate the wheat, many died but some survived. The DDT was passed from the producer (wheat) to the primary consumer (grasshopper). The DDT continued to move up the food chain and its concentration increased in the tissues of the secondary consumers (red-winged blackbirds) and tertiary consumers (peregrine falcons).

By the 1970s, the peregrine falcon population in North America was almost wiped out. The high concentrations of DDT in the birds had caused their eggshells to become thin and break, reducing the numbers of chicks that hatched. The DDT also affected the birds' behaviour, causing them to abandon their nests and chicks.



The use of DDT has been restricted in Canada since 1969. Unfortunately, DDT is non-biodegradable and continues to be found in the environment and in the tissues of higher-level consumers. As a result of the restricted use of DDT, the peregrine falcon is making a slow recovery in Canada.

Various programs are also assisting their recovery. One program introduces captive-bred birds to the wild. Another program installs nesting boxes on tall buildings and skyscrapers. Peregrine falcons have nested in recent years on the Radisson Hotel in downtown Winnipeg and on the McKenzie Seeds Building in Brandon.

Example 2: Mercury and Fish

Mercury is a naturally occurring element that is generally found in low concentrations in air, water, and soil. Small amounts are naturally present in plant, fish, animal, and human tissues.

In 1969, contaminants in fish became a concern in Manitoba with the discovery of high mercury levels in fish from the English-Wabigoon river system in Ontario and in fish from the south basin of Lake Winnipeg. Mercury contamination was also discovered in the Saskatchewan River, which closed commercial fishing on parts of that river. Studies attributed the mercury contamination mainly to pollution from some pulp and paper mills. Restrictions on the use and release of mercury from industry during the 1970s have helped to reduce mercury poisoning in these areas.

High levels of mercury in fish can cause deformations and sometimes death, such as when a fish does not develop fins or gills. Predatory fish, such as walleye and northern pike, will usually have higher mercury residues than bottom-feeding species, such as suckers. Lower mercury residues usually occur in the smaller and younger fish of a species. Remember that as you move up a food chain, the amount of toxin will be larger because each predator eats many prey. A bigger fish will therefore take in toxins on its own, as well as the toxins within all the smaller fish it eats. In humans who eat large amounts of contaminated fish, mercury poisoning can cause damage to the brain and the central nervous system. Mercury is also dangerous to the developing fetus.

Learning Activity 1.6: Bioaccumulation

1. With the use of examples, describe the difference between biodegradable and non-biodegradable substances.
2. Complete the Concept Overview for the term *bioaccumulation*.

continued

Learning Activity 1.6 (continued)

Concept Overview

Key word or concept.

bioaccumulation

Write an explanation or definition in your own words. You will be paraphrasing.

Draw a figurative representation.

List facts (at least five).

Create your own questions about the concept.

Create an analogy.

Concept Overview Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

continued

Learning Activity 1.6 (continued)

3. Explain why there might be higher levels of mercury in a large fish than a smaller one.

Check the Learning Activity Answer Key found at the end of this module.

Summary

Bioaccumulation occurs when an organism takes large amounts of a non-biodegradable substance into its body. Biomagnification occurs when these substances are passed along a food chain, growing in concentration until they begin to affect the health of the organisms.

Assignment 1.2: Toxin Investigation (14 Marks)

Choose a toxic substance from the following list. Find out what humans use the substance for, and how it can become an environmental or health hazard. Finally, describe how you can avoid or reduce exposure to the toxin. Make use of the Internet, the library, and any local experts to help you with your research.

– DDT

– mercury

– lead

– tetrachlorobenzene

– bisphenol A

– another substance of your choosing

You can present your findings as a written report, an 8½" x 11" poster, or a PowerPoint presentation. Your assignment will be assessed using the following rubric.

Content	Length and Style	Sources Used	Total
7 marks	3 marks	4 marks	
■ Describe how humans use the substance. *(2 marks)* ■ Describe how the substance affects human and/or environmental health. *(3 marks)* ■ Explain how people can avoid or reduce exposure to the substance. *(2 marks)*	**Report:** At least 1 typewritten page, double-spaced, using a font no larger than 12. **PowerPoint:** At least 4 slides. Text is in a font and colour that is easy to read. Uses backgrounds, transitions, and pictures to enhance the presentation. **Poster:** On 8½" x 11" paper. Clear title and subheadings. Text is organized into sections. Uses colour and pictures to capture attention.	Include a "Works Cited" page at the end of your report that details all of your research resources. **Books:** Include the title, author, and publisher. **Internet Resources:** Include the Page Name, Author, and URL. **Interviews:** Include the name of each person you interview as well as their occupation and place of work.	
			/14

Notes

Lesson 7: Population Growth

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe the carrying capacity of an ecosystem
- ❑ explain why a population cannot continue to increase in size indefinitely
- ❑ interpret graphs of population growth curves
- ❑ determine if a population is growing, stable, or declining
- ❑ predict the carrying capacity of an environment, based on a population growth curve

Key Words

- carrying capacity
- population growth curve
- population

Introduction

In 1960, the world population was estimated at over three billion people. In 2008, that figure had more than doubled to over six billion. How will the global population grow in the coming decades? How will all of these additional people affect the ecosystems in which they live? Is there a limit to the number of people that Earth can support? This lesson will investigate how populations grow, and the methods used to track and illustrate these changes.

Population Growth

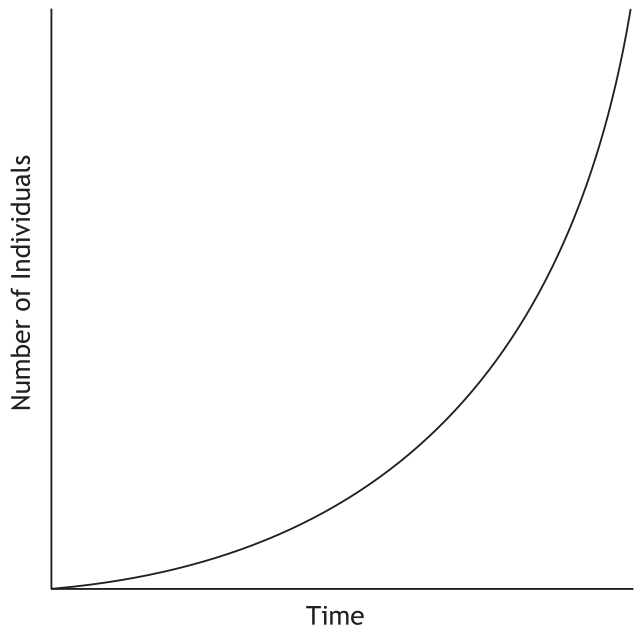
Imagine that you noticed a pair of houseflies in your warm house on a cold day in December. Assuming that one of the flies was a female and the other a male, we would expect them to reproduce. Houseflies lay up to 900 eggs at a time. If the house is warm (approximately 20°C), the eggs will hatch into larvae (a small worm-like stage of fly development) in about one day. The larvae go through several stages of development and become mature houseflies in about a month. If the home remains warm, and the larvae find enough food to eat, there could be approximately 900 flies in your house by January (assuming that all the larvae survive until they become mature flies). If all goes well, hundreds of pairs of these flies will lay hundreds of eggs each, producing approximately 400 000 new flies by late February and, if this continues, you could have an additional 180 000 000 mature flies by the time you open your windows in late March (and maybe let some of the flies out).

As you can see, the number of flies increases slowly at first (in this example, two flies become 900 flies in the first month), then very rapidly (900 flies became 400 000 flies in the second month and 180 000 000 by the third month). Finding a breeding pair of flies in a house in December is not uncommon. Having a few hundred million flies in your home in March is highly unlikely. Why is this so?

To answer questions such as this, ecologists study populations. A **population** is a group of organisms that belong to the same species living in a certain area. For example, all the flies that live in your house are a population, as are all the people who live in the town of Gimli, Manitoba.

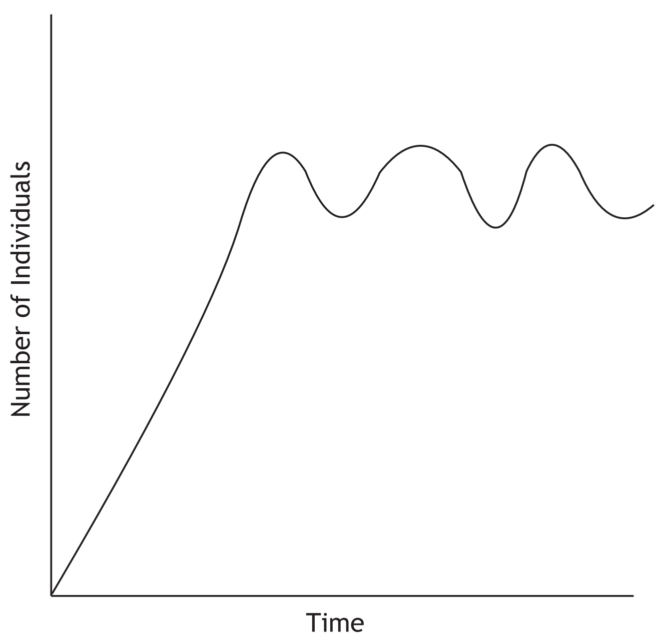
When conditions are ideal for growth and reproduction, a population will experience a rapid increase in size. Initially the population grows slowly, but the larger the population gets, the faster it grows. As more offspring survive and reproduce, even more offspring are born. The graph below illustrates a **population growth curve** of this nature.

Figure 1.2 **Population Growth Curve 1**



Can a population continue to grow at this rate forever? The answer, of course, is no. The environment becomes limiting. Resources such as food and water become harder to find and the rate of population increase begins to slow, as the graph below illustrates.

Figure 1.3 **Population Growth Curve 2**



Compare Figure 1.2: Population Growth Curve 1 and Figure 1.3: Population Growth Curve 2 and note the similarities between the two graphs. In both cases, the population grows slowly at first, but the larger the population gets, the faster it grows. As more offspring survive and reproduce, even more offspring are born.

Now, note the differences between the two graphs. The population growth on the second graph begins to slow. Perhaps resources such as food and water are becoming limited. Perhaps some of the population migrates to a new area to obtain resources. Eventually the population growth on this graph reaches zero, and the size of the population remains fairly stable. This is because the number of deaths in the population equals the number of births.

The formula for determining population growth is as follows:

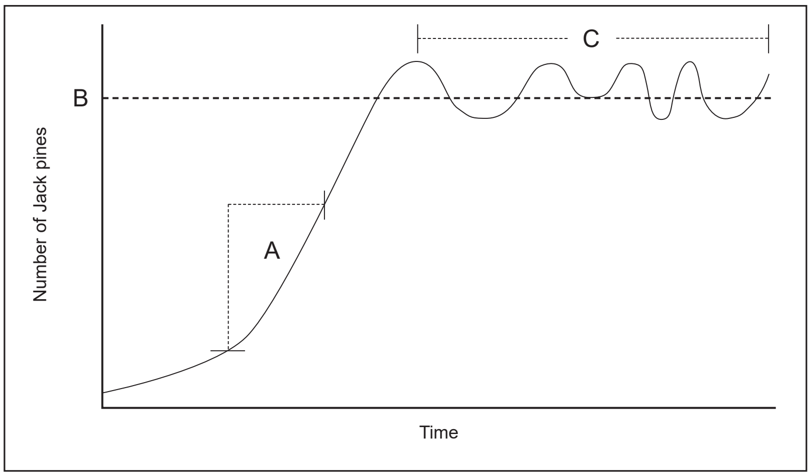
Population growth = (births + immigrants) – (deaths + emigrants)

If population growth is less than zero, there are more deaths and emigrants (organisms that leave the area) in the population than there are births and immigrants (organisms that arrive new to the area). The size of the population begins to decline.

The largest population of a species that a particular environment can support is known as the **carrying capacity**. The carrying capacity of the environment is different at different times. At some times, when resources such as food and water are more abundant, a population can increase in size. At other times, when there is less food, water, and shelter, the population will decline. These population fluctuations occur over time, but the carrying capacity represents an average of a series of ups and downs. If you draw a line through the middle of the population fluctuations, that line represents the carrying capacity of that environment for that species.

Learning Activity 1.7: Exploring Population Growth

Many years ago, a fire swept through the boreal forest in an area of northern Manitoba. The trees, shrubs, and other plants perished in the fire. A team of wildlife biologists decided to study the regrowth of the forest over time. They chose to focus on the Jack pine population as these trees are some of the first to grow back after a fire. A graph of the results of their study is shown below.



1. Why is the number of Jack pines increasing so rapidly in area A of the graph?
2. How do you account for the fluctuations in area C of the graph?
3. What does B represent?
4. Describe, in your own words, what is happening to the Jack pine population in the graph.
5. Predict how the graph would change if another forest fire swept through the region.
6. Predict how the graph would change if a forestry company began to log the area.

Check the Learning Activity Answer Key found at the end of this module.

Summary

So long as individuals are able to successfully reproduce and raise multiple young, a population will grow in number until it reaches the carrying capacity of its ecosystem. In the next lesson you will discover the specific factors that limit population growth.

LESSON 8: FACTORS LIMITING POPULATION GROWTH

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe the factors that limit the size of a population
- ❑ compare and contrast density-dependent and density-independent limiting factors

Key Words

- density-dependent
- competition
- predation
- predator
- prey
- density-independent
- natural occurrence
- human activity
- disease
- stress

Introduction

As you learned in the previous lesson, the size of a population cannot continue to increase indefinitely. Many environmental factors limit the growth of a population. For example, resources such as food and water will affect the size of a population. What are other factors that influence the size of a population?

Limiting Factors

Density-dependent factors affect a population that is crowded. These limiting factors include **competition, predation, disease**, and **stress**. Density-dependent factors act to reduce the size of a population by increasing the death rate and decreasing the birth rate.

Competition: All living things require certain resources for survival. Animals require food, water, living space, and mating partners. Plants require water, sunlight, and living space. As the size of the population increases, the organisms in the population are forced to compete to obtain enough resources to survive. For example, as the size of a herd of cattle in a pasture increases, there may no longer be enough grass to support all the cattle. The cattle will begin to struggle to obtain enough grass to eat. They may begin to lose weight, and some may die of starvation.

Predation: Predation occurs when one organism (the **prey**) serves as food for another (the **predator**). One predator-prey relationship in Manitoba exists between polar bears and seals. If a group of seals in an area has had plenty of food, the seal population will begin to increase. Because polar bears prey on seals, the number of polar bears in the area will also increase because their food supply is more plentiful. The larger number of predators (polar bears) will begin to consume more and more prey (seals). This will cause the number of seals to decline. As fewer and fewer seals are available to eat, the polar bears will begin to go hungry, and their numbers will begin to decline. When only a few polar bears are left, the seals have a greater chance of surviving, and once again their numbers will begin to rise. This creates a cyclic relation in these populations.

Disease: Diseases act as predators in many ways. When an American elm tree gets infected with the fungus that causes Dutch elm disease, it will eventually die. If many other American elms are located nearby, the fungus can easily travel from the infected tree and quickly spread the disease. If the trees are more widely separated, the disease cannot spread as easily and as fast. All populations are susceptible to disease.

Stress: All organisms require a certain amount of living space. In some animals, overcrowding can lead to increased aggression and fights over territory, resulting in injuries and stress. Adults may be wounded, and their offspring may be neglected or orphaned. In other animals, stress can cause pregnant females to miscarry or to stop producing eggs. More animals in the populations will die as a result of stress, and their numbers will decrease.

Density-independent factors affect a population regardless of its size. These limiting factors include **natural occurrences** and **human activity**. Density-independent factors also act to reduce the size of a population by increasing the death rate and decreasing the birth rate.

Natural Occurrences: These are events that occur without human intervention. For example, a lightning strike in a forest can cause a fire that kills most of the plants and animals in an area. A frost will wipe out many insects and annual plants. A cold winter with heavy snowfall may make it difficult for deer to obtain enough grass to survive. Conversely, a warm winter with little snowfall may cause deer populations to increase. A warm winter with thin sea ice will make hunting seals difficult and dangerous for polar bears.

Human Activity: Humans can have a significant impact on the populations of other organisms. A forest may be clear-cut, drastically reducing the number of trees in an area. Marshes may be drained, resulting in the loss of habitat for plants, small mammals, and birds. Grassland that once supported a wide variety of plant and animal species may become housing developments and shopping malls.

Learning Activity 1.8: Limiting Factors

1. Complete the Compare and Contrast form below.

Compare and Contrast

Unit ______________________ Topic ______________________

C O M P A R E

How are density-dependent limiting factors and density-independent limiting factors alike?

C O N T R A S T

How are density-dependent limiting factors and density-independent limiting factors different?

Write a statement to compare and contrast the two terms, concepts, or events.

Compare and Contrast Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

continued

Learning Activity 1.8 (continued)

2. Limiting Factors

   Each of the statements below involves a situation that will affect the growth of a population. Classify each of the statements as DD (density-dependent) or DI (density-independent) and give a reason for your choice.

   a. A lion and cheetah attempt to live in the same area and hunt the same food. The more aggressive lion survives; the cheetah does not.

   b. Coyotes cross the winter pack ice and enter Newfoundland. The moose population starts to decline.

   c. A severe frost wipes out 50 percent of the coffee crop in Brazil.

   d. Careless smoking causes a forest fire, which destroys much of the wildlife in a region of northern Manitoba.

   e. Due to severe overcrowding in an Asian village, many children do not survive to reach adulthood.

   f. Since lynx prey on snowshoe hares, an increase in the hare population causes an increase in the lynx population.

   g. A severe flood in the Red River Valley causes a decline in the deer population.

   h. Due to stress, large numbers of female lemmings miscarry their young and fail to reproduce.

   i. Travellers who visit a crowded African village become infected with a disease caused by parasites.

   j. Many fish die due to a change in the winds and the appearance of the El Niño ocean current off the coast of Peru and Chile.

   k. Because rabbits in Australia have no natural enemies, their population increases rapidly.

   l. Fish on a coral reef stake out their territory and chase away any younger fish that try to live there.

   m. The illegal dumping of industrial pollutants into a river causes a massive fish kill.

Check the Learning Activity Answer Key found at the end of this module.

Summary

Whether a population is large or small in number, it will always be subjected to factors that limit its growth rate. Regardless of size, all populations can be affected by natural occurrences and human activity. Meanwhile, large populations will compete for limited resources, and face disease, stress, and predators. The next lesson will look specifically at the relationship between populations of predators and their prey.

Lesson 9: Population Dynamics

Lesson Focus

After completing this lesson, you will be able to

- ❑ analyze population data
- ❑ construct a population graph
- ❑ interpret graphs of predator-prey relationships
- ❑ describe relationships between the sizes of predator and prey populations
- ❑ account for changes in the size of populations
- ❑ predict future population trends

Introduction

This lesson will examine in closer detail how the density-dependent factor of **predation** affects populations of predators and their prey. You will also have an opportunity to construct a population growth curve in order to better visualize fluctuations in population.

A Predator-Prey Relationship

Now take a closer look at the relationship between predators and prey. One example is that of the lynx and its primary prey, the snowshoe hare. People have long been aware that the populations of both the hare and the lynx fluctuated on a cyclical basis. A team of wildlife biologists decided to study these fluctuations. The team monitored the populations of both lynx and snowshoe hare over a number of years and recorded their observations. The data they gathered is found in the table below.

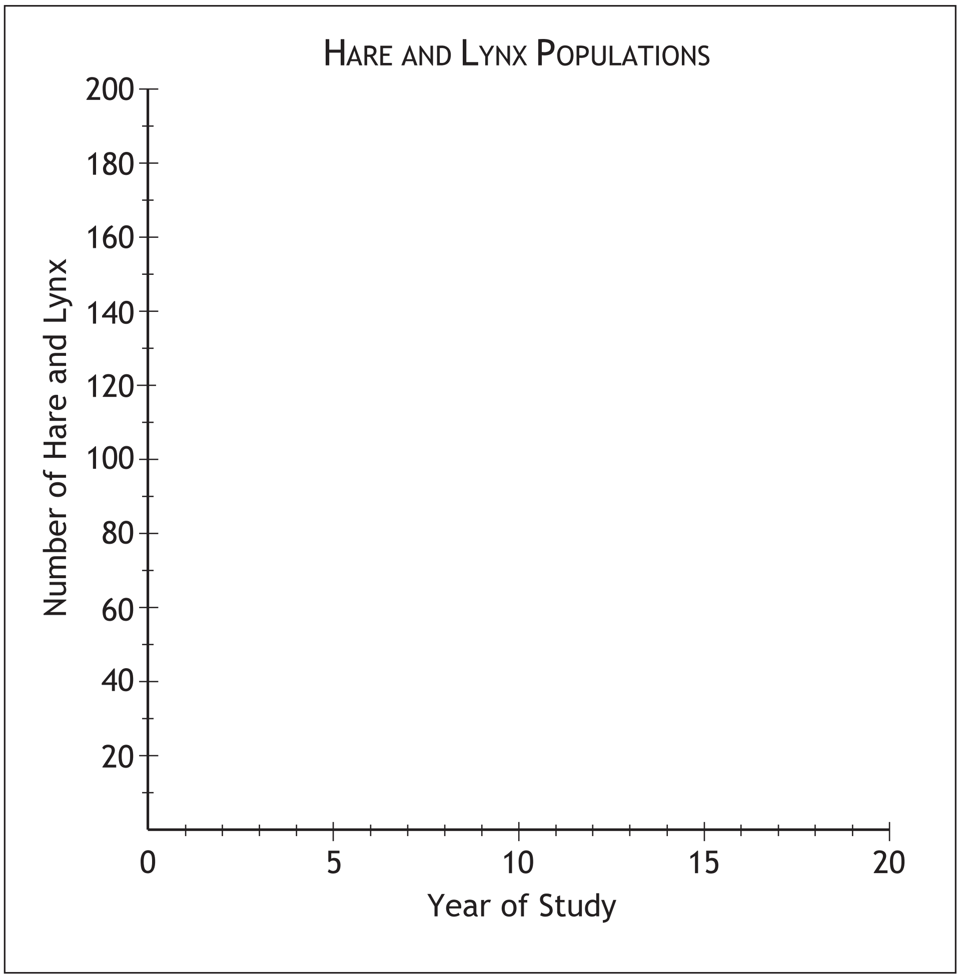
Table 1.1: Populations of Lynx and Snowshoe Hare

Year of Study	Lynx Population	Hare Population	Other Observations
1	30	50	
2	5	25	low lynx birth rate
3	5	50	lynx eating mice—unusual
4	10	70	food is plentiful for hares
5	25	100	
6	45	150	high lynx birth rate
7	65	175	winter food scarce for hares
8	95	160	hares are starving
9	115	100	many hares eaten by lynx
10	100	60	
11	80	40	
12	40	20	lynx are starving
13	5	50	lynx leave the area
14	5	75	
15	10	120	high hare birth rate
16	30	160	
17	60	180	greatest number of hares seen
18	100	150	trees and shrubs badly chewed
19	120	70	greatest number of lynx seen
20	90	45	many young hares die

Your role is that of wildlife biologist. You must examine the data the team has gathered, create a graph showing the changes in the sizes of the lynx and hare populations, and interpret the information. A blank graph has been provided for you to use on the next page.

Learning Activity 1.9: Population Dynamics

1. Examine the population data on Table 1.1. Do you notice any patterns
   a. in the changes in the hare population?
   b. in the changes in the lynx population?
   c. that show one population affecting another?
2. On the following graph or on your own graph paper, plot the fluctuations in the lynx and hare populations for the 20-year study period.



Hint: Complete the broken-line graph for the lynx using one color. Then do another broken line for the hare using a different color.

continued

Learning Activity 1.9 (continued)

3. Examine the biologists' "Other Observations" and your graph to respond to the following.
   a. Suggest possible reasons why the hare population was so high in Year 16 of the study.
   b. Suggest possible reasons why the lynx population was so low in Year 14 of the study.
   c. Suggest possible reasons why the hare population declined from Year 8 to Year 11 of the study.
   d. Suggest possible reasons why the lynx population rose from Year 4 to Year 8 of the study.
   e. Predict the size of the hare population in Year 26 of the study. Explain how you arrived at your prediction.
   f. Write a paragraph or two describing the relationship between lynx and snowshoe hare populations. Include the following terms in your answer: *predator*, *prey*, *carrying capacity*, *competition*. Be sure to refer to the population data and other observations gathered by the team of wildlife biologists.

Check the Learning Activity Answer Key found at the end of this module.

Lesson Focus

After completing this lesson, you will be able to

- ❑ analyze population data
- ❑ construct a population graph
- ❑ interpret graphs of predator-prey relationships
- ❑ describe relationships between the sizes of predator and prey populations
- ❑ account for changes in the size of populations
- ❑ predict future population trends
- ❑ explain how changes in wildlife populations are an important consideration when developing wildlife-management strategies

Introduction

In this lesson you will continue to examine predator-prey population dynamics; this time, you will consider the added factor of human intervention in the case of wolf, deer, and elk populations.

Wildlife Management

In some cultures, wolves have been admired for their ability to work tirelessly together in packs to capture their prey. In other cultures, they have been viewed as dangerous predators whose victims included livestock and humans. Early European settlers to Manitoba attempted to kill off the wolf population to protect their children, cattle, and sheep from predation. What impact did the extermination of wolves have on the ecosystem?

Prior to the introduction of cattle and sheep, wolves preyed on deer and elk in Manitoba's grasslands and forests. When the wolf population went into decline due to human attempts at extermination, deer and elk populations began to increase. The lack of predators in the ecosystem led to a population increase in the prey population. The large numbers of deer and elk began to cause problems for farmers. The deer and elk began to eat crops, and the large herds began to damage farmland. Diseases infected the herds. As a result, the deer and elk populations had to be controlled.

To this day, deer and elk populations are managed by hunting. Deer population estimates remain between 150 000 and 160 000. An historic peak of about 250 000 occurred in the summer of 1995, in contrast to a low of 60 000 in 1974. The number of deer and elk is carefully monitored and this information is used to set bag limits for licensed hunters. When populations are high, limits are increased. High deer populations may contribute to greater numbers of deer-vehicle collisions. Deer and elk grazing continue to damage crops and trees. In an attempt to reduce the damage, feeding programs have been established in some parts of Manitoba.

Today, timber wolves are primarily restricted to our boreal forests and tundra with small populations in southern Manitoba. Manitoba's wolf population numbers approximately 4000 and appears to be stable. An exception is the Riding Mountain population, which decreased during the 1990s. In response to this decline, wolf hunting has been reduced in the Riding Mountain area.

Generally, timber wolves are left alone in the vast majority of their range in the boreal forest and tundra. Some trapping and hunting of wolves is permitted in areas where wolf populations are stable. Where wolves intrude in agricultural areas and prey on cattle and sheep, or where wolves venture into northern communities, measures to control offending animals are implemented.

Some controversy over the control of the wolf population remains to this day. Old prejudices still linger, even though the myths of wolves eating children have been shown to be false. Ranchers lose money when wolves prey on their cattle and sheep. However, their losses must be balanced with the losses suffered by farmers whose crops are eaten, or drivers whose vehicles are damaged in collisions with wildlife.

Gray (Timber) Wolf and White-tailed Deer Fact Sheets: Adapted with permission from material located on the Manitoba Conservation website at:
www.gov.mb.ca/conservation/wildlife/mbsp/fs/grwolf.html and
www.gov.mb.ca/conservation/wildlife/mbsp/fs/wtdeer.html (21 Nov. 2011).

Summary

It is interesting to note that, although carnivorous wolves are presumed to be chief threats to human safety and farming practices, even herbivores such as deer and elk can become hazards for vehicle traffic and agriculture.

Notes

Assignment 1.3: Predator-Prey Interactions (14 marks)

In the 1990s, people became concerned about the wolf and deer populations in a Manitoba provincial park. A wildlife biologist was hired to monitor the populations over 10 years. The results of the study are found below.

Year	Wolf Population	Deer Population
1991	20	4000
1992	24	4600
1993	33	5000
1994	44	4800
1995	56	4500
1996	48	4200
1997	42	3900
1998	36	3850
1999	38	3900
2000	38	3950

1. Using the data in the table, complete the bar graph at the end of this assignment, showing the changes in the deer and wolf populations. The first year is done for you. Select two coloured pencils of your choice. *(4 marks)*

2. Describe the relationship between the wolf population and the deer population. *(2 marks)*

continued

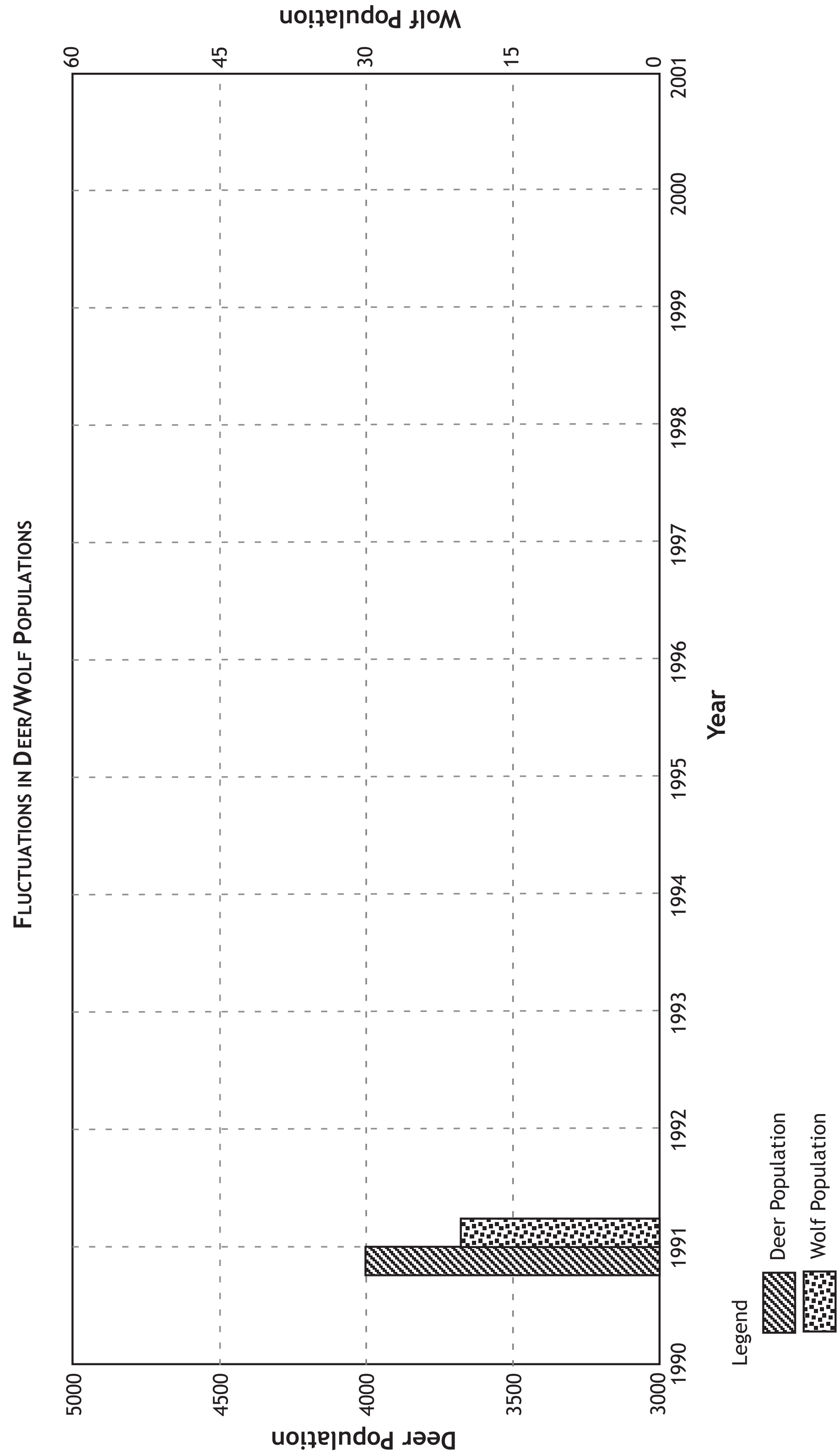
Assignment 1.3 (continued)

3. Describe how the four density-dependent factors could have contributed to these results. *(4 marks)*

4. Population dynamics can also be influenced by density-independent factors. Choose a density-independent factor and describe how it could have contributed to the population dynamics in this 10-year study. Be sure to state what year (or years) that this factor occurred, and how it might have influenced the following years in the study. *(4 marks)*

continued

Assignment 1.3 (continued)



Notes

Lesson 11: Biodiversity

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe the importance of biodiversity to an ecosystem
- ❑ explain how the biodiversity of an ecosystem contributes to its sustainability
- ❑ predict the effect of extinction on an ecosystem

Key Words

- biodiversity
- extinct
- sustainable
- monoculture

Biodiversity

Look outside your window. What different types of plants and animals do you see? Do you recognize any birds or mammals? What about trees and shrubs? The variety of organisms found within an ecosystem is known as its **biodiversity**. The biodiversity of an ecosystem is an indicator of its stability and health. Stable and healthy ecosystems will have a large number and variety of species present.

Different types of ecosystems have differing numbers and types of organisms present. The producers, consumers, and decomposers in Brazil's tropical rainforest are quite different from those in Canada's tundra. You don't see many polar bears in Brazil, and you don't see many parrots in the Arctic. The biodiversity of an ecosystem may also appear to change through the year. You certainly do not see many mosquitoes or robins here in the winter.

Sustainability

Stable and healthy ecosystems are **sustainable**, which means they are renewable and can continue without the addition of new materials. They rely on the undisturbed cycling of nutrients and the natural biodiversity of the area to maintain predator-prey relationships.

For example, compare the sustainability of a natural prairie grassland to that of a homeowner's lawn. The biodiversity of the grassland is much greater than that of the lawn. Different plants, including those that can "fix" nitrogen, are present. In contrast, a lawn is a **monoculture**. Only one type of plant (grass) is present. As grasses cannot "fix" nitrogen, the lawn ecosystem can only be sustained with the addition of fertilizer on a regular basis.

The biodiversity of a natural prairie grassland helps protect it from predators. While grasshoppers consume grasses, their population is kept in check by predators such as red-winged blackbirds. Other plant species may not be harmed by grasshoppers and will continue to grow.

In contrast, monocultures are more susceptible to pests. Because monocultures are a large concentration of a small number of species, they are more vulnerable to attack. A lawn requires the addition of herbicides to keep it weed-free, and the addition of insecticides to reduce the damage caused by insects.

Effects of Extinction

As you recall from previous lessons, organisms are linked together in complex food webs. Should one species in an ecosystem become **extinct**, the entire food web may be affected. A species is considered to be extinct when it is no longer found anywhere on our planet. Extinction disturbs predator-prey relationships.

Review the food web diagram in Module 1, Lesson 2: Energy Flow. How would the removal of wild rice affect the Lake Winnipeg ecosystem? As you can see from the diagram, wild rice is a producer. It is an important food source for primary consumers such as minnows and red-winged blackbirds. A lack of wild rice could result in a shortage of food for these primary consumers. The red-winged blackbird and minnow populations will begin to decline.

This, in turn, would affect the populations of secondary consumers that prey upon them. The number of loons, bullfrogs, snapping turtles, and northern pike would be reduced. Finally, the number of tertiary consumer populations (e.g., eagles) would begin to fall as well. You can see how the removal of one species can have a large impact on an ecosystem. It can lead to a domino effect: one event can cause a large chain reaction.

Learning Activity 1.10: Biodiversity

1. A homeowner's lawn is a monoculture and contains only one species of plant. Can you think of other examples of ecosystems that are made up of a single species?
2. Complete the Concept Overview on the following page for the term *biodiversity*.

continued

Check the Learning Activity Answer Key found at the end of this module.

Summary

In the past, we often did not concern ourselves with the importance of biodiversity to our planet. As our knowledge of ecology has grown, we have become more aware of the need for biodiversity in maintaining and preserving ecosystems, including the survival of our species.

Learning Activity 1.10 (continued)

Concept Overview

Key word or concept.

biodiversity

Draw a figurative representation.

Create your own questions about the concept.

Write an explanation or definition in your own words. You will be paraphrasing.

List facts (at least five).

Create an analogy.

Concept Overview Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Lesson 12: Species Extinction

Lesson Focus

After completing this lesson, you will be able to

- ❑ discuss the potential consequences of species extinction to an ecosystem
- ❑ differentiate between the following terms: *extirpated species*, *endangered species*, *threatened species*
- ❑ describe how Manitoba's *Endangered Species Act* is designed to ensure the survival of species at risk

Key Words

- species at risk
- extirpated species
- endangered species
- threatened species
- *Endangered Species Act*

Introduction

The previous lesson highlighted the importance of biodiversity in preserving ecosystems, and the domino-effect risks of removing even a single species from an environment. In this lesson you will examine several cases of endangered species within Manitoba and the measures being used to help their survival.

Learning Activity 1.11: Species at Risk in Manitoba

Read the articles "Manitoba's Species at Risk: In Danger of Disappearing" and "Manitoba's Species at Risk: Piping Plover" on the following pages.

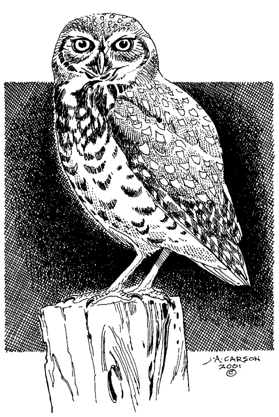
continued

Manitoba's Species At Risk

In Danger of Disappearing

Manitoba is Taking Action

Because every plant and animal species at risk faces its own threats and has its own specific needs, efforts to help each one vary. Manitoba Conservation is taking specific action for each listed species, in partnership with government agencies, non-government partners and knowledgeable individuals.



Grassland birds, such as the Burrowing owl, have declined throughout their range due to loss of habitat in both their breeding and wintering ranges

Species at risk are defined as plants and animals in danger of disappearing from all, or part, of their natural range. Natural range refers to the area, large or small, where species normally live.

Extinction Rate is Increasing

Plants and animals have come and gone as long as there has been life on earth, with many reasons for their extinction. Today, however, the rate at which species are becoming extinct appears to be increasing. In addition, more species seem to be showing signs of decline. Possible causes include:

- habitat loss due to human population growth
- alien invasive species outcompeting native ones
- the earth's changing climate

The situation is often worse for species found at the edge of their range, especially if there is little habitat available. In such cases, these species may be even more at risk.

Protecting Species at Risk

Many countries, provinces and states have laws to protect species at risk of extinction. Manitoba passed its *Endangered Species Act* in 1990; Canada passed the *Species at Risk Act* (SARA) in 2003. These acts protect certain species from harm and propose plans for recovery.

Manitoba's *Endangered Species Act* prohibits activities that would:

- kill, disturb or interfere with any listed species
- damage, destroy or remove habitat and natural resources that listed species depend on

Possession of listed species is prohibited. Manitoba's conservation minister may grant permits for exceptions to these rules for scientific research or reintroduction efforts.

Protecting species at risk can be complicated. Many are found in areas of heavy human use. Protection plans must balance the interests of the species at risk and the people they co-exist with. In Manitoba, recovery planning efforts take these factors into consideration by bringing different people and organizations together to find solutions to these problems.

Four Categories of Species

Under Manitoba's *Endangered Species Act*, species may be legally designated in one of four categories:

- Extinct species are species that have disappeared completely from earth.
- Endangered species are species that are at risk of disappearing throughout all, or most, of their Manitoba range.
- Threatened species are species that are likely to become endangered due to low or declining numbers in Manitoba, if the factors affecting them do not improve.
- Extirpated species are species that were once native to Manitoba, but have disappeared throughout all of their former range. Extirpated species may still be found elsewhere or in captivity.

In addition, there is a watch list of special concern species. These species are not regulated under the act but could be in the future. The list of species changes over time. Visit www.manitoba.ca/conservation/wildlife or contact Manitoba Conservation's Wildlife and Ecosystem Protection Branch for a current list.

Protecting & Managing *our Future*

Manitoba

Source: Manitoba Conservation. *Manitoba's Species At Risk: In Danger of Disappearing*. www.gov.mb.ca/conservation/wildlife/sar/pdf/sar_overview.pdf (17 Feb. 2012). Reproduced with permission from Manitoba Conservation.

continued

Manitoba's Species At Risk

Cool Facts

Many of Manitoba's species at risk, such as the Piping plover and Western prairie fringed-orchid, are at risk throughout their entire range. Others, such as the Great Plains ladies'-tresses, are considered common in nearby provinces and states.

•

Extirpated species such as the Whooping crane and Grizzly bear are occasionally observed in Manitoba. These species, however, will remain listed as extirpated until confirmed as regular breeding residents in Manitoba.

•

Species at risk are often clustered together, based on their habitat preferences such as grassland birds on mixed-grass prairies in southwestern Manitoba, or tall-grass prairie species in southeastern Manitoba. Multi-species recovery plans may be needed to examine how to conserve all of them, especially in cases where their needs may differ.

Western spiderwort can be displaced from its sandhill habitat by Leafy spurge, an invasive plant that is difficult to control.

Landowners Can Do their Part

If you are working on land that supports species at risk, good planning can help minimize potential harm to these species. Landowners can:

- conduct work outside of breeding season and other sensitive periods
- move work away from sensitive habitats
- learn more about the species and how to reduce negative effects

Landowners with species at risk on their property may wish to provide voluntary protection though a conservation agreement. This agreement allows landowners to protect natural ecosystems, fish and wildlife habitat and plant or animal species while continuing to use and develop their land.

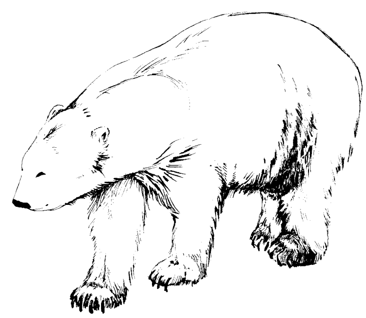
Help Conserve Species at Risk

If you are interested in conserving Manitoba's biodiversity, including species at risk, you are encouraged to get involved. Consider participating in citizen-based monitoring projects such as the Christmas Bird Count or the Piping Plover Guardian Program. Become informed about conservation programs and share this information with friends, family and the community. Commit to any action that reduces our impact on the environment, including conserving energy, driving less often and reducing waste and water use.

For more information on Manitoba's species at risk and what can be done to conserve them, please contact:

Manitoba Conservation
Wildlife and Ecosystem Protection Branch

Box 24, 200 Saulteaux Crescent
Winnipeg MB
R3J 3W3
(204)945-7775
toll free 1-800-214-6497
www.manitoba.ca/conservation/wildlife

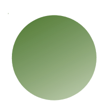


Polar bears are threatened by loss of sea ice, due to climate change, along the western coast of Hudson Bay.

Extirpated Species
Any species once native to Manitoba that has disappeared through all of its Manitoba range. Extirpated species are declared as such by regulation under the *Endangered Species Act*.

Endangered Species
Any native Manitoba species threatened to disappear through all or most of its Manitoba range. Endangered species are declared as such by regulation under the *Endangered Species Act*.

Threatened Species
Any native Manitoba species likely to become endangered or at risk due to low or declining numbers in Manitoba if the factors affecting it don't improve. Threatened species are declared as such by regulation under the *Endangered Species Act*.



Special Concern Species
Species not regulated under the *Endangered Species Act* but which could eventually be considered Endangered or Threatened if the factors affecting them do not improve.

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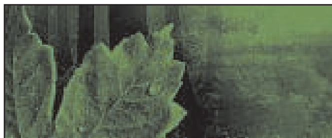
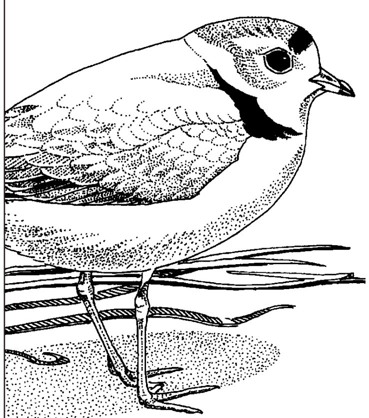


Manitoba's Species At Risk

Endangered

Any native Manitoba species threatened to disappear through all or most of its Manitoba range. Endangered species are declared as such by regulation under the *Endangered Species Act*.



Piping plover

Charadrius melodus

The Piping plover *(Charadrius melodus)* is a provincially and nationally endangered bird, found in many provinces and states, including Manitoba. It is a stocky shorebird with a white breast, abdomen and rump and pale brown to grey back, head and wings. It is identifiable by a black stripe across the forehead from eye to eye, a long white eyestripe and a single black band across the chest. The Piping plover resembles both the Semipalmated plover (but is lighter in colour), and the Killdeer (but is smaller and has one band across its chest, not two).

During breeding season, the bird's colours become brighter. A black tipped orange bill, orange legs and a black band reaching from eye to eye across the forehead, vibrantly stand out on the breeding Piping plover.

Habitat

The Piping plover can be found on lakeshores and river sandbars. It nests on gravel shores of shallow, saline lakes and on the sandy shores of larger prairie lakes. It tends to use only unvegetated or sparsely vegetated areas for nesting.

Life History

The Piping plover arrives at its breeding grounds in Manitoba in late April or May. Once paired, the male scrapes a shallow nest in the sand or gravel, which he will present to the female for her inspection. The nest is often lined with shells or pebbles, which keeps the eggs off the wet sand, drains rainwater and acts as camouflage.

In May, the female lays two to four cream-coloured eggs covered with small dark spots.

In June, the chicks hatch and emerge fully feathered. Within hours they can run and feed on their own. They can fly between 20 and 25 days after hatching. Migration begins in early August when the birds leave for the wintering grounds.

Piping plovers feed on small insects and worms found on the surface of the sand along shorelines.

Distribution

The Piping plover has three distinct locations of breeding in North America: the northern Great Plains, the Great Lakes region and the Atlantic coast. The wintering grounds include the southern Atlantic shore of the United States and the Gulf of Mexico coastline. In Canada, Piping plovers breed along the Atlantic shore, Lake of the Woods in northwestern Ontario, and along lakeshores and saline wetlands of southern Manitoba, Saskatchewan and Alberta. In Manitoba, Piping plovers are most consistently found nesting on broad beaches along Lake Winnipeg, Lake Manitoba, West Shoal Lake, and occasionally Oak Lake and Whitewater Lake.

Status

The Piping plover is considered provincially rare by the Manitoba Conservation Data Centre, and globally uncommon by the Association for Biodiversity Information. Threats to the Piping plover include loss of habitat due to human use of beaches, all terrain vehicle traffic, and pets. High water levels can flood nests and reduce important feeding areas, while low water levels allow encroachment of vegetation and reduce the beach area. Piping plover predators include gulls, crows, Northern harriers, skunks, raccoons, foxes and coyotes.

The Piping plover is listed as Endangered by regulation 25/98 under the Manitoba *Endangered Species Act*. It has also been

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Manitoba Conservation

Source: Manitoba Conservation. *Manitoba's Species At Risk: Piping Plover*. www.gov.mb.ca/conservation/wildlife/sar/pdf/pplover.pdf (17 Feb. 2012). Reproduced with permission from Manitoba Conservation.

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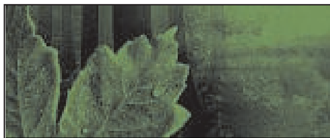


Manitoba's Species At Risk

Cool Facts

When the eggs or young are threatened, adults attempt to lure the danger away by feigning a wing injury. The adult will fly away once the predator is a safe distance from the nest.

•

Most summers, Piping plovers share Grand Beach with thousands of sunseekers. To help protect the birds, Provincial Park staff fence off plover nesting areas.

•

The Great Plains population of Piping plovers is the largest, consisting of approximately 1,400 breeding pairs.

•

There have been no successful Piping plover nests recorded on the Great Lakes for over 20 years.

assigned a status of Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). It is listed in the United States *Endangered Species Act*, and in many provincial and state endangered species acts. It is also protected in Canada under the federal *Migratory Birds Convention Act*.

Continent wide surveys in 1991 and 1996 suggest that there are approximately 2,700 pairs in North America with almost 900 pairs found to breed in Canada. In Manitoba, the numbers of Piping plovers have declined from over 100 pairs in the late 1980's to fewer than 20 pairs in recent years.

Stewardship and Recovery

The Piping plover Recovery team has a goal of maintaining and increasing the prairie population. To make this goal a reality, more awareness and education about the Piping plover and its habitat are important.

To improve Piping plover breeding success, people must be willing to share beaches with these birds. This might require completely fencing off designated nesting areas and placing predator enclosures over nests to protect the eggs.

Get Involved in Recovery

If you see a Piping plover on your property, congratulations. Your land management skills have helped to maintain the population of one of Canada's rarest birds. Contact the Wildlife Branch, or your nearest Manitoba Conservation office, if you would like more information on what you can do to further enhance your land for this and other native Manitoba plant and animal species.

You can help by learning to identify these birds and avoid disturbing nesting areas during June and July. Also, as a landowner, you can maintain natural habitat around wetlands and reduce disturbances by humans, pets and livestock.

If you see a Piping plover, contact Manitoba Conservation at one of the numbers listed below.

Manitoba Conservation
Wildlife Branch
Box 24, 200 Saulteaux Crescent
Winnipeg, Manitoba
R3J 3W3
(204) 945-7764
www.gov.mb.ca/natres/wildlife/index.htm

•

Manitoba Conservation
Regional Offices

Eastern Region
Lac du Bonnet
(204) 345-1427

Central Region
Gimli
(204) 642-6077

Western Region
Brandon
(204) 726-6450

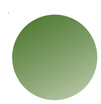
•

Partners in production of this fact sheet:
Manitoba Conservation, Wildlife Branch
Environment Canada, Canadian Wildlife Service

Extirpated Species
Any species once native to Manitoba that has disappeared through all of its Manitoba range. Extirpated species are declared as such by regulation under the *Endangered Species Act*.

Endangered Species
Any native Manitoba species threatened to disappear through all or most of its Manitoba range. Endangered species are declared as such by regulation under the *Endangered Species Act*.

Threatened Species
Any native Manitoba species likely to become endangered or at risk due to low or declining numbers in Manitoba if the factors affecting it don't improve. Threatened species are declared as such by regulation under the *Endangered Species Act*.



Vulnerable Species
Species not regulated under the *Endangered Species Act* but which could eventually be considered Endangered or Threatened if the factors affecting them do not improve.

Learning Activity 1.11 (continued)

1. Use the article "Manitoba's Species at Risk: In Danger of Disappearing" to respond to the following.
   a. In your own words, define the following terms: *extirpated species, endangered species, threatened species*. Provide examples of Manitoba species for each of the categories. A current list is available on the Manitoba Conservation website at www.gov.mb.ca/conservation/wildlife/sar/sarlist.html.
   b. Describe how Manitoba's *Endangered Species Act* is designed to ensure the survival of species at risk.
2. Use the article "Manitoba's Species at Risk: Piping Plover" to respond to the following.
   a. Identify possible natural occurrences that have led to the decline of the piping plover population.
   b. Identify possible human activities that have led to the decline of the piping plover population.

Check the Learning Activity Answer Key found at the end of this module.

Lesson 13: Species Introduction: A Case Study

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe potential threats to an ecosystem caused by an introduced species
- ❑ discuss potential economic consequences of introducing new species to an ecosystem

Introduction

Removing a species from an ecosystem can upset the balances of food webs and biodiversity. At the same time, introducing a new species into a new ecosystem can have consequences that are just as dangerous. In this lesson, you will investigate the case of zebra mussels in North America, and determine how species introduction can affect the environment and human activities.

Learning Activity 1.12: Species Introduction

Read the Information Bulletin "Zebra Mussels in North America" on pages 79 to 82. Please note that this article is somewhat out of date—zebra mussels have been reported in watersheds flowing into Manitoba. Respond to the following:

1. Describe some of the economic problems that have been created by the introduction of zebra mussels to North America.
2. What are the characteristics of zebra mussels that have allowed them to spread so quickly?
3. Why are zebra mussels so abundant in the areas to where they have spread?
4. How do zebra mussels affect an ecosystem?
5. Why is Manitoba a likely target for zebra mussel invasion?
6. What can you do to help prevent the spread of zebra mussels?

Check the Learning Activity Answer Key found at the end of this module.

Zebra Mussels in North America

Zebra mussels have caused millions of dollars of damage in Europe, the Great Lakes region of Ontario, and the United States. This damage includes:

- Plugging cooling water systems of boat motors;
- Clogging water intakes of private cottages, towns, cities, and industries;
- Severely reducing recreation at beach areas due to the accumulation of sharp shells and foul odours from decaying, dead zebra mussels; and
- Reducing species of algae and microscopic aquatic animals which are important in the food chain.

Colonies of zebra mussels have formed layers up to 1.5 metres (five feet) thick in some water use facilities. Over 700,000 zebra mussels per square metre of surface were located in 1989 within the water intake canal of a power plant near Lake Erie. The flow of drinking water was reduced by 60 per cent, requiring costly repairs and the emergency shutdown of non-essential services in one Michigan city.

These huge colonies of zebra mussels filter tremendous amounts of water removing small particles such as algae. In Lake Erie, the increased water clarity is providing greater light penetration, causing rooted aquatic plants to flourish. As a result, underwater plants are now clogging some harbours. In addition, the preferred food of zebra mussels is green algae. In certain areas of Lake St. Claire, green algae has virtually disappeared, resulting in increased occurrences of the toxin producing blue-green algae.

What are zebra mussels?

The zebra mussel (*Dreissena polymorpha*) is a small animal that resembles freshwater clams. Zebra mussels grow up to five centimetres (two inches) in length and may live up to five years. Their name originated from the brown and white striped colour of its shell. One mature female zebra mussel can produce up to 40,000 eggs per year for a total of 150,000 eggs during its life span. Typically, they become sexually mature in their second year. Eggs are released into the water by the female and are fertilized by nearby males.

Are zebra mussels in Manitoba?

No. Nor have zebra mussels been reported from any of the watershed that flows into Manitoba. They have been located in Lake Superior at Thunder Bay and Duluth, and in the Upper Mississippi River at St. Paul, Minnesota.

In June 1999, dead zebra mussels were found in Manitoba on the hull of a boat traillered from Orillia, Ontario. The mussels were recognized by an alert marina worker who contacted the proper authorities. The boat was thoroughly cleaned before launching into the Red River.

Each year, Manitoba Conservation, in co-operation with the Canadian Coast Guard, examines hundreds of navigational and marker buoys for zebra mussels. Buoys from many Whiteshell lakes, the Winnipeg River, the Red River, and the south and north basin of Lake Winnipeg are examined. The City of Winnipeg monitors near its water intake and Manitoba Hydro monitors its facilities on the Winnipeg and Red rivers. No zebra mussels have been found in Manitoba waters.

Many southern prairie rivers are at high to moderate risk of successful zebra mussel colonization should they be introduced accidentally into these waters. Rivers and lakes in eastern Manitoba (for example, in the Whiteshell Provincial Park) are at lower risk.

Why do zebra mussels spread so rapidly from one body of water to another?

Laboratory studies have shown that adult zebra mussels can survive out of water, in moist conditions, for up to two weeks. They attach to boats or other equipment being transported from one body of water to another and spread to new areas.

Zebra mussel larvae can also survive long periods of time in water with sufficient oxygen. As a result, larvae may be unknowingly transported in live wells, bilge water, residual engine cooling water, or floating pontoons, and infest new waters. Because of the large number of tourists, pleasure boaters, and anglers moving between the infested waters of the Great Lakes, or the Upper Mississippi River systems, and Manitoba, there is a high probability that zebra mussels could invade Manitoba lakes and streams.

All surface waters flowing into Manitoba eventually flow north as part of the Hudson Bay drainage basin. Land-bridges to the south and east of this basin are natural barriers which protect the province from watersheds infested with zebra mussels. The land-bridges, however, are short in distance, and traillered watercraft could easily transport zebra mussels into our watershed. Zebra mussels could enter Manitoba through either the Red River system from the south or the Winnipeg and Rainy River systems from the east.

Where did zebra mussels originate?

Until recently, they were found only in Europe. Native to the Caspian, Black, and Azov seas of eastern Europe, they were initially discovered in the Caspian Sea in 1769. During the past century they have migrated through central and western Europe. It is thought that zebra mussels were transported to North America in the ballast water of an ocean-going vessel. This ballast water was then discharged in Lake St. Clair, Ontario, likely in early 1986. Scientists first discovered a population of zebra mussels in Lake St. Clair in 1988.

How far have zebra mussels spread in North America?

Since zebra mussels were first introduced into Lake St. Clair, they quickly spread from the Great Lakes to the Erie Canal, Finger Lakes, and the Hudson River area of the eastern United States. They have been found in the Trent-Severn and Rideau Canal areas of eastern Ontario. Zebra mussels can now be found in the Mississippi River from St. Paul, Minnesota, to the Gulf of Mexico delta, including its major tributaries, the Ohio, Illinois, and the Arkansas rivers.

Why are zebra mussels so abundant?

- They colonize surfaces that are not inhabited by other similar organisms and have few natural predators; zebra mussels may be controlled by some natural fish and bird predators such as carp, sturgeon, gulls, and mergansers;
- An extremely successful reproductive strategy ensures that many young zebra mussels will survive even in poor environmental conditions;
- Thread-like filaments form a very strong bond between the zebra mussel and solid surfaces. This allows them to remain attached even in habitats with high water flows, such as water intakes and water lines;
- Zebra mussels can filter large quantities of water to remove food (mainly algae or plankton), and, therefore, can live in a variety of water bodies with a wide range of available food. It is estimated that one adult zebra mussel can filter all of the material out of one litre of water in one day.

What is the Province of Manitoba doing about the zebra mussel threat?

The Province of Manitoba is involved in a number of initiatives to educate and heighten public awareness about zebra mussels. These include highway signage, production of brochures and factsheets, informational articles, and presentations to target audiences. Monitoring for zebra mussels is carried out by the City of Winnipeg at Shoal Lake, Manitoba Hydro stations on the Winnipeg River, and Manitoba Conservation by inspecting seasonal marker buoys from various water bodies.

What can I do to help?

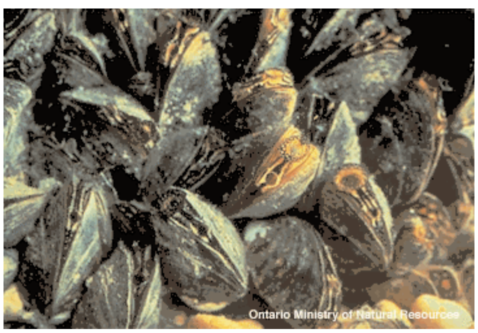
Before leaving infested waters, follow this five-point checklist:

1. Drain all bilge water and rinse bait buckets.
2. Inspect all equipment.
3. Scrape off 'grainy' surfaces (they could be young zebra mussels).
4. Wash your boat with hot, soapy water.
5. Dry equipment in the hot sun for three to five days, then scrape off remaining zebra mussels.

The best method of control is reducing the risk of accidental introduction. Once zebra mussels establish in Manitoba waters, they cannot be eradicated.

If I take these precautions, will it help?

Although it takes time and effort to clean zebra mussels from boating and other equipment, it will save large sums of money for costly repairs and will give researchers an opportunity to find suitable control methods.



If you are a cottage owner, commercial fisherman, angler, lodge owner, or if you work in a water treatment plant, electrical power generating station, or marina, please check equipment, docks, piers, or other underwater structures for the presence of zebra mussels.

If you think you have located zebra mussels in Manitoba or need further information, please contact Manitoba Conservation.

Lesson 14: Decision Making and Environmental Issues

Lesson Focus

After completing this lesson, you will be able to

- ❑ define sustainability
- ❑ explain how the decision-making process can be used to make decisions about sustainability

Key Word

- sustainability

Introduction

Canada has been recognized as one of the best places in the world to live. Our abundant natural resources, such as clean water and forests, have created many economic opportunities for Canadians. We have invested in strong health-care and education systems. As a result, we are the envy of many nations.

However, we do not live in a perfect country. Pollution threatens our air and water. Farmland is disappearing under growing towns and cities. Fisheries are shutting down as fish are vanishing or are too toxic to eat. How can we build a society that maintains our standard of living, yet is responsible for preserving our environment for future generations of Canadians?

Sustainability

We must create a society that values the sustainability of our resources and environment.

Sustainability refers to the conservation, protection, and regeneration of natural resources and environment over time. In order to make decisions about sustainability, we require knowledge of social, economic, and environmental issues and the relationships among them. An important part of sustainability is the idea that our decisions today affect our future health and well-being, the economy, and the environment.

Decision Making

The decision-making process can be used to make any informed, responsible decision. The following example outlines the steps of this process.

Step 1:	***Identify the issue and raise a question.*** **Example:** Should you get your driver's licence?	
Step 2:	***Research the implications of your decision.*** **Examples:** I may have more freedom. *(positive)* Gas and parking will cost me money. *(negative)*	What are the *positive* and *negative* effects of this decision?
Step 3:	***Evaluate your research and develop possible courses of action.*** **Example:** You decide you do want your licence.	Your choices are to go ahead and get your learner's permit or to first enrol in a local driver training course.
Step 4:	***Carefully make your decision and develop an action plan.*** **Example:** You decide to take a driver training course first.	You call several driving schools and book your session.
Step 5:	***Reflect on your decision and the process you used.*** **Example:** Did you consider all the options?	Are you happy with the decision? What could you have done differently?

There are some additional points to consider. All groups need to be consulted and asked for input. Individuals must carefully examine their priorities, habits, beliefs, and values. In order to achieve a balance among differing groups, some compromises may need to be made.

Summary

As a citizen of Canada and of the world, you can play an active part in making informed and responsible decisions about social, economic, and environmental issues for today and the future. We all have an important role to play in ensuring our decisions are sustainable for meeting our present and future needs.

Notes

Assignment 1.4: Hydroelectric Power Decisions (22 marks)

1. The demand for hydroelectric power is increasing across Manitoba, Ontario, and Minnesota. Our province has an abundance of rivers that offer the potential for developing new hydroelectric sites. Back in the early 2000s, a decision had to be made as to whether Manitoba Hydro should build a new generating station on the Burntwood River between the communities of Nelson House and Thompson.

   a. If you were a project consultant, from which groups would you seek advice before a decision was made? *(3 marks)*

   b. Can you identify possible negative and positive effects if the project goes forward? Remember to consider social, economic, and environmental issues. *(4 marks)*

continued

Assignment 1.4 (continued)

c. Can you identify possible negative and positive effects if the project does not go forward? *(4 marks)*

d. What are some possible courses of action that could be taken? What compromises may need to be made? *(2 marks)*

continued

Assignment 1.4 (continued)

e. What would your decision be? What are the long-term consequences of that decision? *(3 marks)*

2. Reflect upon all you have studied in this module and develop a list of life practices that promote sustainability. Be sure to include health and well-being, the economy, and the environment. *(6 marks)*

Notes

End of Module 1

Congratulations, you have just completed the first module in the course. In this module, you are assessed by completing the Module 1 assignments as well as the first half of the midterm examination. You will be writing the midterm examination at the end of Module 2.

So what should you do now? After sending Assignment Package 1 to the Distance Learning Unit, start working on Module 2. Once you have completed Module 2, you will be ready to write the examination.

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: Biochemical Cycles
- ❑ Assignment 1.2: Toxin Investigation
- ❑ Assignment 1.3: Predator-Prey Interactions
- ❑ Assignment 1.4: Hydroelectric Power Decisions

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

Notes

Module 1

Learning Activity Answer Key

Module 1
Learning Activity Answer Key

Learning Activity 1.1: Introduction to Ecology

1. Define *ecology*, *ecologists*, and *ecosystems*. How are they related to one another?

   Ecology is the study of the interactions among organisms and the interactions between organisms and their environment.

   Ecologists are scientists who study ecology.

   Ecosystems are areas of the planet consisting of the physical environment and the living things within it.

   All three terms are related because they all involve living things and their environments. They all include the Greek word *oikos*, which means house.

2. Consider the Lake Winnipeg ecosystem described in the introduction. Write a descriptive paragraph that illustrates a local ecosystem with which you are familiar. It could be a local park, your yard, a forest, or a pond. Be sure to include a variety of abiotic and biotic factors in your descriptive paragraph, as well interactions among them.

   ***Abiotic* factors in the ecosystem could include water (or snow and ice, sunlight). Other abiotic factors in the ecosystem could include nutrients, soil, oxygen in the air and water, or the temperature of the air or water.**

   ***Biotic* factors include the following:**

   ***Plants:* land plants (e.g., spruce trees, wheat, daisies), water plants (e.g., bulrushes, algae)**

   ***Animals:* mammals (e.g., bear, deer, mice), birds (e.g., eagles, chickens, robins), fish (e.g., pickerel, whitefish), reptiles and amphibians (e.g., frogs, turtles, snakes), insects (e.g., black flies, grasshoppers, water beetles), other invertebrates (e.g., snails, worms, clams, jellyfish)**

   ***Fungi* (e.g., mushrooms, puffballs, slime mould)**

   Bacteria

3. How does a niche differ from a habitat?

   The place in which an organism lives is its habitat. An organism's niche is a combination of its habitat and the role it plays in an ecosystem.

4. What would happen to an ecosystem if all the decomposers were destroyed?

   If all the decomposers in an ecosystem were destroyed, the remains of dead plants and carcasses of dead animals would not be recycled. Garbage such as food waste and sewage would accumulate in the ecosystem. Necessary nutrients would not be put back into the soil, slowing the growth of plants and animals.

5. One student argues that humans are producers because they produce their own food by growing crops and raising livestock. Do you agree? Why or why not?

   The student is not correct. Humans are consumers because we are animals. Animals cannot trap sunlight and create food. Only plants, which are producers, are able to do this.

Learning Activity 1.2: Energy Flow

1. Why is it more energy-efficient for humans to eat grains and vegetables rather than meat?

   Sunlight is used directly by plants that create grains and vegetables. Because herbivores must consume grains to produce meat, only about 10 percent of the energy in grain is turned into energy in meat.

2. Why is sunlight needed to maintain an ecosystem?

   Sunlight is the ultimate source of energy for all living things in ecosystems. It is captured by plants, and used by plants and animals.

3. Complete the following chart.

Definition	Term	Example
an organism that consumes plants/producers, also known as primary consumers	Herbivore	**– rabbit** **– moose** **– cattle**

Definition	Term	Example
an organism that consumes other animals	Carnivore	**– wolves** **– northern pike** **– ladybugs**

Definition	Term	Example
an organism that feeds on dead animals	Scavenger	**– blowflies** **– turkey vultures** **– ravens**

Definition	Term	Example
an organism that feeds on both producers/plants and consumers/animals	Omnivore	**– black bears** **– red-winged blackbirds** **– humans**

Learning Activity 1.3: Comparing and Contrasting Processes

1. Complete the following Compare and Contrast frame for the terms *photosynthesis* and *cellular respiration*.

Compare and Contrast

C O M P A R E

How are photosynthesis and cellular respiration alike?

- **Both are processes in the carbon cycle and the oxygen cycle.**
- **Both involve energy and glucose.**
- **Both processes are done by plants.**

C O N T R A S T

How are photosynthesis and cellular respiration different?

- **Photosynthesis creates glucose; cellular respiration breaks down glucose.**
- **Photosynthesis creates oxygen and glucose; cellular respiration uses oxygen and glucose.**
- **Photosynthesis uses the Sun's energy to create glucose; cellular respiration uses glucose to create energy so organisms can grow, move, reproduce, et cetera.**
- **Plants can do both photosynthesis and cellular respiration; animals can only do cellular respiration.**

Write a statement to compare and contrast the two terms, concepts, or events.

The carbon cycle uses the process of photosynthesis to capture the Sun's energy and turn it into glucose. The oxygen cycle uses the process of cellular respiration to break down glucose and release energy that organisms use to survive.

Compare and Contrast Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Learning Activity 1.4: The Carbon Cycle

1. Explain how deforestation, fire, and combustion of fossil fuels disrupt the balance between photosynthesis and cellular respiration.

   Deforestation reduces the amount of vegetation present so less photosynthesis occurs. Carbon dioxide levels can increase. Fire and fossil fuel combustion all produce carbon dioxide, but photosynthesis cannot remove it all. The balance between photosynthesis and cellular respiration is disrupted because the excess carbon dioxide cannot be removed from the atmosphere.

2. A slogan of the environmental movement is "Think globally. Act locally." How does this slogan apply to the increasing atmospheric carbon dioxide levels and to changing your lifestyle to help reverse this trend?

   By thinking globally, we can be more aware of the worldwide impact of increased carbon dioxide levels. By acting locally, we can adjust our lifestyles so that we can begin to do our part to reduce our carbon dioxide output.

3. Why might it be difficult to change some of our actions that disturb the carbon cycle? Give specific examples.

   Many obstacles stand in the way of reducing the human disruption of the carbon cycle. Some people may not want to adjust their lifestyles to reduce their carbon dioxide output. Some people may think that their contribution would be so small that it's not worthwhile to change their lifestyle. Other people may not believe global warming is actually occurring. Still others may believe that global warming is a good thing for a cold country like Canada.

Learning Activity 1.5: The Nitrogen Cycle

1. Predict the time of the year in which an algal bloom is most likely to occur. Explain the reasons for your prediction.

   The spring melt will cause excess nitrate and ammonia to run off farmers' fields. Farmers apply fertilizer to their fields in late spring, and a heavy rainstorm will cause the fertilizer to wash off the fields. As a result, an algal bloom is most likely to occur in the summer. The long days of summer provide much sunlight and the waters of the lakes and rivers warm up.

2. Describe ways in which human health can be affected by disturbed nitrogen cycling.

   Drinking water containing toxic algae from an algal bloom can cause stomach upset and diarrhea. In children, the ingestion of nitrates can cause a blood disorder called methemoglobinemia.

3. How can fertilizer and manure enter lakes and rivers?

   Excess manure can wash off the land and into lakes and rivers during the spring snowmelt or a heavy rainstorm. Excess fertilizer runs off farmers' fields and peoples' lawns and gardens in the same way.

4. Can you identify human activities that should not be taking place in waters in which an algal bloom is occurring?

   Swimming should not take place because a person could ingest algal toxins from the water. Fish caught in such water may contain algal toxins and make a person sick if he or she eats it. Exposing one's skin to such water can lead to algal toxins irritating the skin.

5. Backcountry campers are advised to bury their feces in the ground and to avoid washing pots and dishes in the lakes and rivers. Why do you think this is so?

   Backcountry campers do not have access to modern toilet and washing facilities. Burying feces will prevent them from being washed into lakes and rivers. The feces will decompose slowly underground and not enter surface water. Waste water from dishwashing may also contain nitrate and ammonia that should not be dumped into lakes and rivers.

Learning Activity 1.6: Bioaccumulation

1. With the use of examples, describe the difference between biodegradable and non-biodegradable substances.

   Biodegradable substances, such as dead plants, dead animals, and sewage, naturally break down over time in the environment.

   Non-biodegradable substances, such as DDT, mercury, glass, and some plastics, persist in the environment over long periods of time.

2. Complete the Concept Overview for the term *bioaccumulation*.

   Key word: **bioaccumulation**

   Explanation: **It occurs when non-biodegradable substances, such as DDT, begin to accumulate in organisms. The substances move up the food chain from producers to consumers, and increase in concentration.**

   Five facts (there are others): **DDT is a pesticide used to control insect pests. The use of DDT was restricted in Canada in 1969. DDT causes peregrine falcon eggshells to thin and break. By the 1970s, the peregrine falcon population in North America was almost wiped out. Peregrine falcons are making a slow recovery in Canada today.**

   Figurative representation: **Perhaps a picture of a food chain showing an increasing amount of DDT inside each organism.**

Create questions: **Perhaps questions such as "Do I have any DDT inside me? What is the effect of DDT on humans? Why didn't the DDT kill all the grasshoppers? How long will DDT remain in the environment?"**

Analogy: **Student answers will vary.**

3. Explain why there might be higher levels of mercury in a large fish than a smaller one.

   Mercury does not dissolve in water, so when a fish has some in its body it will get stored (accumulate) in its tissue. Even if there is only a small amount of mercury in a small fish, the predator at the real trophic level will eat many small fish at one time. The bigger fish will store all the toxins that come from the smaller fish it eats. This happens at every trophic level. The higher the trophic level, the greater the concentration of toxins like mercury.

Learning Activity 1.7: Exploring Population Growth

1. Why is the number of Jack pines increasing so rapidly in area A of the graph?

   The carrying capacity has not been reached. Environmental conditions are ideal for growth and reproduction. There are enough resources such as sunlight and water for all the Jack pines to survive and produce offspring.

2. How do you account for the fluctuations in area C of the graph?

   At times, resources such as water are abundant and the number of trees will increase. At other times, resources are scarce (for example, during a drought) and the number of trees will decrease.

3. What does B represent?

   B represents the carrying capacity of the environment.

4. Describe, in your own words, what is happening to the Jack pine population in the graph.

   Initially after the fire there are very few Jack pines. Then the number of trees begins to increase very rapidly. Eventually the population growth begins to slow. When the carrying capacity is reached, the average size of the Jack pine population remains the same. However, there are fluctuations in the populations on a yearly basis.

5. Predict how the graph would change if another forest fire swept through the region.

   If another forest fire swept through the region, the population would decline dramatically so that there would only be a small number of Jack pines.

6. Predict how the graph would change if a forestry company began to log the area.

   If a forestry company began to log the area, the number of Jack pines would decrease. The extent of the decrease would depend on how many trees were logged.

Learning Activity 1.8: Limiting Factors

1. Complete the Compare and Contrast form below.

   Compare

   - **Both types of factors limit population size.**
   - **Both types of factors cause the size of populations to fluctuate over time.**
   - **Humans can affect both types of factors. For example, by eliminating predators such as wolves, humans can cause an increase in the deer population. Humans can also decrease the deer population by increasing the bag limit, allowing hunters to harvest more deer.**

   Contrast

   - **Density-dependent factors usually operate only when a population is large and crowded. Density-independent factors operate regardless of the size of the population.**
   - **Density-dependent factors include competition, predation, disease, and stress. Density-independent factors include natural occurrences and human activity.**

2. Limiting Factors Worksheet

   Each of the statements below involves a situation that will affect the growth of a population. Classify each of the statements as DD (density-dependent) or DI (density-independent) and give a reason for your choice.

   a. A lion and cheetah attempt to live in the same area and hunt the same food. The more aggressive lion survives; the cheetah does not.

      DD—There is competition between the lion and the cheetah for food.

   b. Coyotes cross the winter pack ice and enter Newfoundland. The moose population starts to decline.

      DD—The coyotes are new predators and begin to prey on the moose.

   c. A severe frost wipes out 50 percent of the coffee crop in Brazil.

      DI—Frost is a natural event that will affect an entire population, regardless of how many or how few coffee plants there are.

   d. Careless smoking causes a forest fire, which destroys much of the wildlife in a region of northern Manitoba.

DI—A forest fire will affect the living things in an area, regardless of how many or how few plants and animals there are.

e. Due to severe overcrowding in an Asian village, many children do not survive to reach adulthood.

DD—Overcrowding may cause stress, increase rates of disease, or cause food shortages, causing children to die.

f. Since lynx prey on snowshoe hares, an increase in the hare population causes an increase in the lynx population.

DD—Increased availability of prey means more food is available for predators, and more can survive.

g. A severe flood in the Red River Valley causes a decline in the deer population.

DI—A natural occurrence, such as a flood, will cause the deer to die by drowning or from a lack of food. It doesn't matter how many or how few deer live in the area.

h. Due to stress, large numbers of female lemmings miscarry their young and fail to reproduce.

DD—Stress can cause females to stop reproducing when populations are overcrowded.

i. Travellers who visit a crowded African village become infected with a disease caused by parasites.

DD—When many people are crowded together, diseases and parasites can be easily spread.

j. Many fish die due to a change in the winds and the appearance of the El Niño ocean current off the coast of Peru and Chile.

DI—El Niño is a natural occurrence that will affect the fish living in the area.

k. Because rabbits in Australia have no natural enemies, their population increases rapidly.

DD—A lack of predators can cause the size of a population to increase dramatically.

l. Fish on a coral reef stake out their territory and chase away any younger fish that try to live there.

DD—All animals require living space. Fights over territory are more common when animals are crowded.

m. The illegal dumping of industrial pollutants into a river causes a massive fish kill.

DI—Human activity, such as polluting the water, will affect the fish in a river, whether few or many fish live there.

Learning Activity 1.9: Population Dynamics

1. Examine the population data on Table 1.1. Do you notice any patterns
   a. in the changes in the hare population?

      Initially the hare population is very low. The number of hares increases from years 2–7, decreases from years 8–12, increases from years 13–17, and then begins to decrease again. The hare population appears to rise and fall in a 10-year cycle.

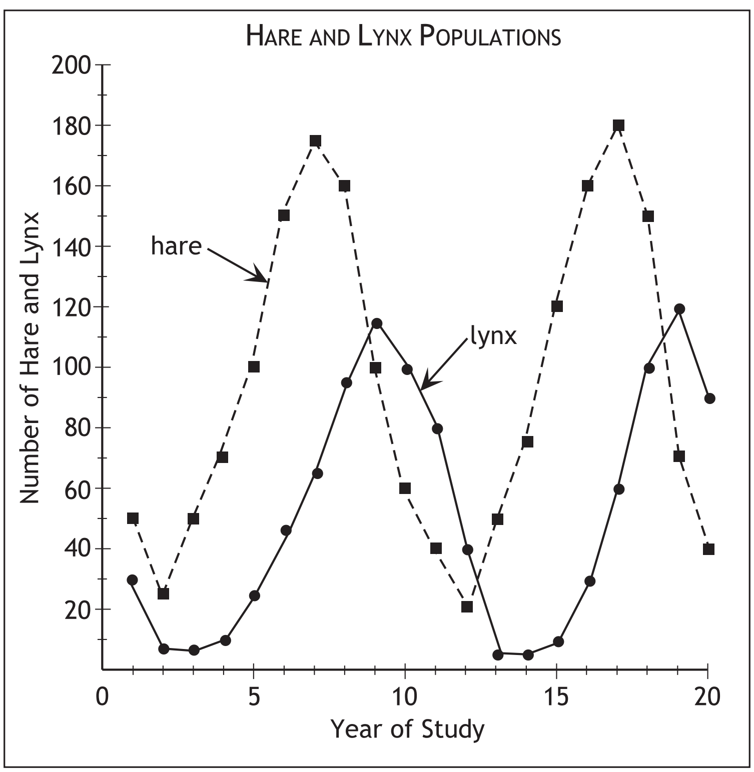
   b. in the changes in the lynx population?

      Initially the lynx population appears to be getting smaller. Then the number of lynx increases from years 3–9, decreases from years 10–13, increases from years 14–19, and then begins to decrease again. The lynx population appears to rise and fall in a 10-year cycle.

   c. that show one population affecting another?

      The rise and fall of the lynx population closely follows the rise and fall of the hare population. A decline in the hare population is followed a year or two later by a decline in the lynx population. A similar pattern can be seen when the hare population rises. An increase in the number of hares is followed within a few years by an increase in the number of lynx.

2. On the following graph or on your own graph paper, plot the fluctuations in the lynx and hare populations for the 20-year study period.



3. Examine the biologists' "Other Observations" and your graph to respond to the following.

   a. Suggest possible reasons why the hare population was so high in Year 16 of the study.

      The hare population in Year 16 is quite high because the number of lynx was low.

      The lower number of predators allowed the population of prey to increase as fewer hare were eaten by lynx. Also, the hare birth rate was quite high the previous year, resulting in more offspring.

   b. Suggest possible reasons why the lynx population was so low in Year 14 of the study.

      The lynx population in Year 14 is quite low because the number of hares had been quite low in previous years. The smaller number of hares probably resulted in the starvation of lynx and low lynx birth rates. Also, some lynx had left the area in search of food.

   c. Suggest possible reasons why the hare population declined from Year 8 to Year 11 of the study.

      The hare population declined for two reasons. First, the observations that trees and shrubs were very gnawed and that winter food was scarce indicate the hare population was so large it may have exceeded the carrying capacity of the area.

      Some hares probably starved to death. Second, the number of lynx in the area was quite high. The increased predator population required a large number of prey to sustain it. More lynx ate more hare, causing a decline in the hare population.

   d. Suggest possible reasons why the lynx population rose from Year 4 to Year 8 of the study.

      The lynx population rose because there was plenty of food available. The hare population had also been increasing rapidly, so plenty of food are available for the lynx. Because there was less competition between the lynx for food, a high lynx birth rate resulted in a larger number of lynx.

   e. Predict the size of the hare population in Year 26 of the study. Explain how you arrived at your prediction.

      Answers will vary.

   f. Write a paragraph or two describing the relationship between lynx and snowshoe hare populations. Include the following terms in your answer: *predator*, *prey*, *carrying capacity*, *competition*. Be sure to refer to the population data and other observations gathered by the team of wildlife biologists.

Lynx are predators. They prey primarily on snowshoe hares. The size of the lynx population is closely linked to the size of the hare population. When there are few hares in an area, there is a lot of food available for the hares to eat. The birth rate increases, and the hare population gets larger. When the number of hares increases, so does the lynx population. There is more food available for the lynx.

But the hare population cannot continue to grow forever. It reaches the area's carrying capacity. With so many hares, food becomes scarce. Some hares may starve to death. The large lynx population preys upon more and more hares. The hare population begins to decline. With fewer hares available, competition between the lynx for food begins to increase. Some lynx may starve to death. Other lynx may leave the area to look for food. This causes the lynx population to decline.

Learning Activity 1.10: Biodiversity

1. A homeowner's lawn is a monoculture and contains only one species of plant. Can you think of other examples of ecosystems that are made up of a single species?

   Other examples of monocultures include fish farms, orchards, hog and chicken barns, cattle feedlots, fields of wheat or canola, and the grass on soccer fields or baseball diamonds.

2. Complete the Concept Overview for the term *biodiversity*.

   Definition: **Biodiversity is all the different types of organisms that live in an ecosystem.**

   List five facts: **Possible facts include**

   - **Stable and healthy ecosystems will have a large number and variety of species present.**
   - **Different types of ecosystems have differing numbers and types of organisms present.**
   - **Stable and healthy ecosystems are sustainable; they are renewable and can continue without the addition of new materials.**
   - **The biodiversity of a natural prairie grassland helps protect it from predators.**
   - **A species is considered to be extinct when it is no longer found anywhere on our planet.**

   Figurative representation: **One possible representation could show a number of different organisms, such as a dog, a fish, a fly, a flower, a tree, or a mushroom. Another might show a sketch of Noah's Ark, labelled "Earth," with the heads of animals looking out.**

Create questions: **Possible questions include**

- **Have any organisms in Manitoba gone extinct recently? How has their extinction affected the ecosystem?**
- **Could we save the DNA of extinct organisms and recreate them by genetic engineering?**
- **If lawns are not sustainable ecosystems, why do so many people have them?**

Create an analogy: **One possible analogy follows:**

Biodiversity is like a jigsaw puzzle. All the pieces (organisms) fit together to create a whole picture (sustainable ecosystem). However, if one piece is missing, the puzzle is incomplete.

Learning Activity 1.11: Species at Risk in Manitoba

1. Use the article "Manitoba's Species at Risk: In Danger of Disappearing" to respond to the following.
   a. In your own words, define the following terms: *extirpated species*, *endangered species*, *threatened species*. Provide examples of Manitoba species for each of the categories. A current list is available on the Manitoba Conservation website at www.gov.mb.ca/conservation/wildlife/sar/sarlist.html.

   A species is extirpated when it has disappeared from the area in which it once lived, but it may live in other areas. For example, the grizzly bear is an extirpated Manitoba species.

   A species is endangered when it is threatened to disappear throughout its range. For example, the peregrine falcon is an endangered Manitoba species. A species is threatened when it is likely to become endangered or is at risk due to low or declining numbers. For example, the Great Plains toad is a threatened Manitoba species.

   b. Describe how Manitoba's *Endangered Species Act* is designed to ensure the survival of species at risk.

   The *Endangered Species Act* identifies extirpated, endangered, and threatened species for protection. It prohibits human activities that would kill, disturb, or interfere with any protected species. It also prohibits human activities that damage, destroy, or remove habitats and natural resources that protected species depend upon for living and breeding.

2. Use the article "Manitoba's Species at Risk: Piping Plover" to respond to the following.
   a. Identify possible natural occurrences that have led to the decline of the piping plover population.

      Nests can be flooded by sudden rainstorms that cause lake levels to rise. Drought can cause lake levels to fall so the beach area is reduced for nesting. Only two to four eggs are laid at a time, so populations cannot increase rapidly. Nests are built on the ground so they are exposed to predators.
   b. Identify possible human activities that have led to the decline of the piping plover population.

      Humans disturb or destroy nests by driving over them with ATVs, and by flooding them with wakes from boats and personal watercraft. Humans stress nesting birds by walking or swimming nearby. Pets damage nests or eat eggs.

Learning Activity 1.12: Species Introduction

Read the Information Bulletin "Zebra Mussels in North America" and respond to the following.

1. Describe some of the economic problems that have been created by the introduction of zebra mussels to North America.

   Economic problems created by the introduction of zebra mussels include plugging cooling water systems of boat motors; clogging water intakes of private cottages, towns, cities, and industries; and severely reducing recreation at beach areas due to the accumulation of sharp shells and foul odours from decaying dead zebra mussels.
2. What are the characteristics of zebra mussels that have allowed them to spread so quickly?

   Adult zebra mussels can survive out of water, in moist conditions, for up to two weeks. They attach to boats or other equipment being transported from one body of water to another and spread to new areas. Zebra mussel larvae can also survive long periods of time in water with sufficient oxygen. As a result, larvae may be unknowingly transported in live wells, bilge water, residual engine cooling water, or floating pontoons, and infest new waters.
3. Why are zebra mussels so abundant in the areas to where they have spread?

   They colonize surfaces that are not inhabited by other similar organisms and have few natural predators; they have an extremely successful

reproductive strategy, which ensures that many young zebra mussels will survive even in poor environmental conditions; thread-like filaments form a very strong bond between the zebra mussel and solid surfaces—this allows them to remain attached even in habitats with high water flows, such as water intakes and water lines; zebra mussels can filter large quantities of water to remove food (mainly algae or plankton) and, therefore, can live in a variety of water bodies with a wide range of available food.

4. How do zebra mussels affect an ecosystem?

   Zebra mussels reduce species of algae and microscopic aquatic animals, which are important in the food chain. In Lake Erie, the increased water clarity is providing greater light penetration, causing rooted aquatic plants to flourish. As a result, underwater plants are now clogging some harbours. In addition, the preferred food of zebra mussels is green algae. In certain areas of Lake St. Claire, green algae has virtually disappeared, resulting in increased occurrences of the toxin-producing blue-green algae.

5. Why is Manitoba a likely target for zebra mussel invasion?

   A large number of tourists, pleasure boaters, and anglers move between the infested waters of the Great Lakes, or the upper Mississippi River systems, and Manitoba. Trailered watercraft could easily transport zebra mussels into our watershed. All surface waters flowing into Manitoba eventually flow north as part of the Hudson Bay drainage basin, so zebra mussels can spread through the whole province.

6. What can you do to help prevent the spread of zebra mussels?

   Clean zebra mussels from boating and other equipment before leaving infested waters and follow the five-point checklist. Check equipment, docks, piers, or other underwater structures for the presence of zebra mussels. Contact Manitoba Conservation or Manitoba Water Stewardship if you spot any zebra mussels.

Grade 10 Science (20F)

Module 2

Chemistry in Action

This module contains the following:

Module 2: Introduction

Welcome to Module 2: Chemistry in Action. This module will give you the chance to examine the interactions among elements as they form compounds through chemical reactions. This module is very important, because we all use chemicals in our everyday lives, and we need to be informed in order to make good decisions.

Learning Activities

There are several learning activities placed throughout this module, which will help you to 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.

Assignments

When you have completed the assignments for Module 2, submit your completed 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.

Assessment Checklist

- ❏ Lesson 4 — Assignment 2.1: Atoms and Ionic Compounds
- ❏ Lesson 7 — Assignment 2.2: Atomic Bonding
- ❏ Lesson 10 — Assignment 2.3: Conservation of Mass
- ❏ Lesson 12 — Assignment 2.4: Chemical Reactions
- ❏ Lesson 14 — Assignment 2.5: Acids and Bases
- ❏ Lesson 16 — Assignment 2.6: Chemistry in Technology and the Environment

These assignments will be worth a portion of the 60 percent of the total marks you will receive for assignments in this course.

What Will You Need?

In order to complete this module, you will need access to the following:

Optional Resources

- Access to a school laboratory (and supervising teacher) or access to the following equipment (and supervising parent/guardian) is needed to perform the optional laboratory activity in Learning Activity 2.11.
  - balance
  - Erlenmeyer flask (125 mL)
  - effervescent antacid tablet
  - balloon
  - warm water (25 mL)
- Access to a school laboratory (and supervising teacher) or access to the following equipment (and supervising parent/guardian) is needed to perform the optional laboratory activity in Learning Activity 2.14.
  - safety goggles
  - red and blue litmus paper
  - test tubes and test-tube racks
  - indicators (universal indicator, phenolphthalein, bromothymol blue)
  - pH metre or pH test paper
  - eyedroppers
  - microtray
  - samples of acids and bases (milk of magnesia, ammonia window cleaner, vinegar, lemon juice, tomato juice, drain cleaner, carbonated drinks, shampoo, black coffee, laundry detergent, milk, salt water, tap water, baking soda, apples)
  - samples of metals (copper, zinc, iron, magnesium)
  - hydrochloric acid (6M), acetic acid (6M), sodium hydroxide (0.5M), calcium hydroxide (0.5M)

Midterm Examination

You will write the midterm examination when you have completed Module 2 of this course. The midterm examination is based on Modules 1 and 2, and is worth 20 percent of your final mark in this course.

To write the midterm examination, you will need to apply for it, as described in the course Introduction.

Lesson 1: Review of the Atomic Model

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
- ❑ calculate the atomic mass of an element, knowing the mass number and atomic number of the atom

Key Words

- subatomic particle
- energy levels
- atomic mass
- atomic mass unit (u)
- atomic number

Introduction

It has taken scientists a long time to understand the basic structure of an atom. Many scientists have carefully worked together to learn the structure of atoms.

You have studied this development in Grade 9 Science. We will use a short review to refresh your memory about the structure of atoms that is relevant to your study this year.

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**. A subatomic particle is a part of an atom, much the same as a wheel is part of a car. The three main subatomic particles are **protons**, **neutrons**, and **electrons**. The scientists Thompson, Rutherford, Bohr, Moseley, and Chadwick were largely responsible for developing an understanding of subatomic particles. Today, scientists know subatomic particles in turn can be broken down into still smaller particles.

The Bohr model of the atom suggested that electrons travel in a circular orbit or **energy level** in a well-defined path. Scientists have done experiments to show that this is not the path electrons actually travel. Electron location and movement is more complicated than Bohr thought; however, the planetary model of the atom is used because it is easier to understand and is adequate for a beginning course in chemistry.

The **modern atomic theory** states that an atom consists of the following:

- Protons are located in the nucleus of the atom. Protons have a positive charge and have a mass of one **atomic mass unit (u)**. An atomic mass unit is defined as 1/12th the mass of a carbon atom that has six protons and six neutrons. This 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**.
- Electrons are located around the nucleus in less well-defined orbits than first thought. Electrons have a single negative electrical charge but their mass is considered zero since it is so small (approximately 1/2000 the mass of a proton).

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 sum of the masses of the protons and neutrons in the nucleus.

Proton mass + neutron mass = total mass

- 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 **atomic mass number** is equal to the sum of the number of protons and neutrons. The atomic mass is expressed in atomic mass units (u).

Number protons + number neutrons = atomic mass number

Electrons

- Electrons move around the nucleus in specific paths called **energy levels**.
  - Energy levels exist whether there is an electron in them or not.
  - Electrons occupy certain energy levels depending on the atom. For example, hydrogen has a single electron in the first energy level; sodium has two electrons in the first energy level, eight electrons in the second energy level, and one electron in the third energy level.
  - An atom can have a maximum of two electrons occupying the first energy level, eight in the second energy level, and eight in the third energy level. We will not study the structure of atoms with more than three levels of energy levels. Each energy level must be filled before electrons occupy the next one.
  - Electrons are so light, they are considered to have zero mass.
  - Electrons have a negative electric charge (–1).

Learning Activity 2.1: Subatomic Particles

Fill in the table below.

	Charge	Location	Mass
Protons			
Electrons			
Neutrons			

Check the Learning Activity Answer Key found at the end of this module.

Atoms

All atoms are made of protons, neutrons, and electrons. A proton in a carbon atom is the same as a proton in an oxygen atom. The same is true for electrons and neutrons. So, if all atoms are made of the same subatomic materials, what determines the difference between atoms of different elements? The answer is that atoms of different elements have different numbers of protons in the nucleus and electrons around the nucleus.

Atomic Number

Henry Moseley originally developed the concept of atomic numbers. The atomic number is equal to 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 six, oxygen has an atomic number of eight, and so on.

Mass Number

All atoms are given a mass number. The mass number is equal to the number of protons plus the number of neutrons; for example, carbon has six protons and six neutrons.

The mass number for carbon would be 6 (protons) + 6 (neutrons) = 12.

Mass number = atomic number (number of protons) + number of neutrons

The atomic mass of an atom is expressed in **atomic mass units** (u). This means the atomic mass of carbon is expressed as 12 u.

Mass number can be expressed as a number with no unit (12 for carbon), and atomic mass is expressed using the same number with a unit (12 u for carbon) called atomic mass units.

Solve for atomic number and number of neutrons by modifying the formula shown above, as follows:

Atomic number = mass number – number neutrons

Number of neutrons = mass number – atomic number

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; that is, 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 neutrons = mass number – atomic number

Table Summarizing Calculation of Number of Subatomic Particles

Number protons	Atomic number
Number neutrons	Mass number – Atomic number
Number electrons	Atomic number

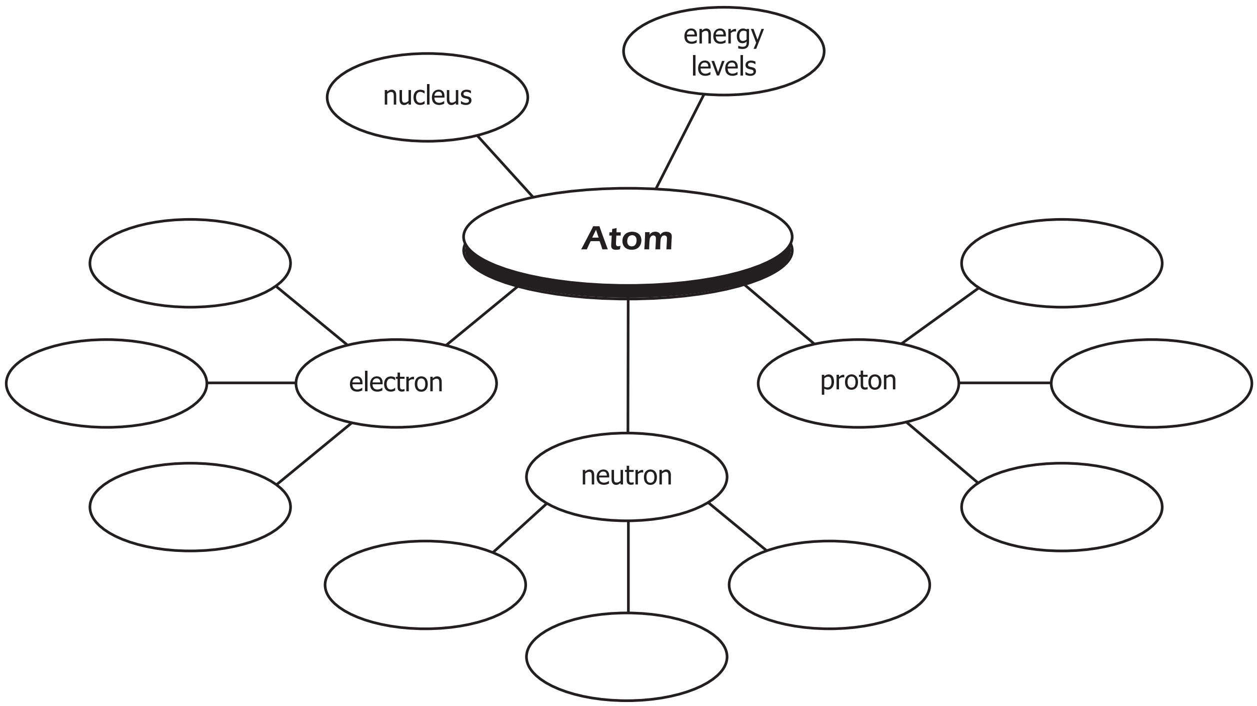
Learning Activity 2.2: Subatomic Particles Review

1. An atom of gold has an atomic number of 79 and an atomic mass of 197 u.
   a. How many protons are in one atom of gold?
   b. How many electrons are in one atom of gold?
   c. How many neutrons are in one atom of gold?
   d. How many protons are in 10 atoms of gold?
   e. What is the atomic mass of gold?
   f. What is the mass number of gold?
2. What is the unit of atomic mass called and what is its symbol?
3. An atom of uranium has an atomic number of 92 and an atomic mass of 238 u.
   a. How many protons are in one atom of uranium?
   b. How many electrons are in one atom of uranium?
   c. How many neutrons are in one atom of uranium?
   d. How many protons are in 10 atoms of uranium?
   e. What is the atomic mass of uranium?
   f. What is the mass number of uranium?

continued

Learning Activity 2.2 (continued)

4. Concept maps show connections between ideas. The start of a concept map is shown below. Complete the concept map using the terms below.



one u	no charge	negative charge
positive charge	travels around nucleus	one u
mass very small	located in nucleus	located in nucleus

Check the Learning Activity Answer Key found at the end of this module.

Summary

- An atom is made of protons, neutrons, and electrons. Electrons occupy set energy levels around the nucleus. For the purposes of this course, we will think of them as moving in orbits, although this is not true.
- The atomic number is equal to the number of protons. The atomic number identifies the atom.
- Atomic mass is equal to the number of protons plus the number of neutrons.

Lesson 2: Bohr Atoms

Lesson Focus

After completing this lesson, you will be able to

- ❑ draw a Bohr model of an atom, when given the number of protons, neutrons, and electrons in the atom
- ❑ describe the meaning of the energy level number

Key Words

- energy level
- planetary model
- valence electrons

Introduction

Niels Bohr was one of the most influential physicists of the twentieth century. He developed a model that explained the arrangement of subatomic particles in an atom. The Bohr model provided a theory as to how and why atoms interact with one another to form larger molecules. Chemists and physicists no longer consider the Bohr model as the best description of the atom. However, the basic ideas of Bohr's model are useful as an introduction to how atoms work. This lesson will explain the details of the Bohr model atom.

Bohr's Atomic Model

From Rutherford's experiments, scientists knew electrons occupy the space somewhere outside the nucleus of the atom.

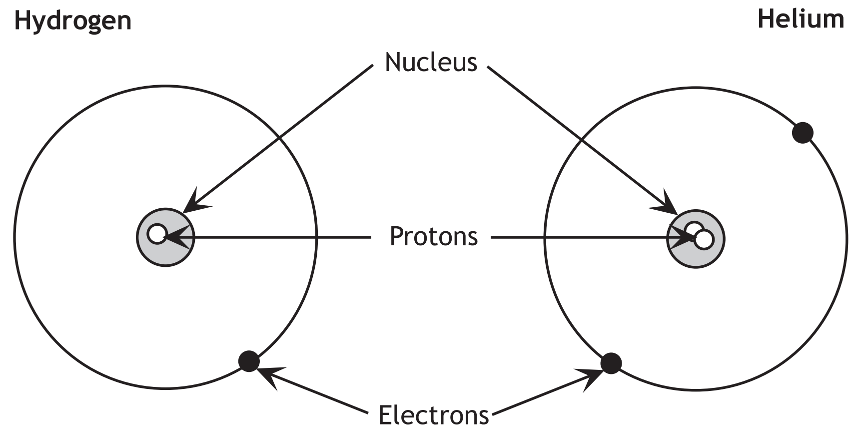
When sunlight passes through a prism, a rainbow of colours appear. This spread of colours is called the spectrum of white light. Scientists had noticed that when electricity was passed through a tube containing a single elemental gas (like hydrogen), they would observe a spectrum that was not a full rainbow—they would only see a few colours spaced apart from each other. They also observed that each gas would always produce its own, distinct spectrum. Hydrogen always produced only four colours.

Bohr theorized that the electrons in hydrogen atoms were becoming more energetic or "excited" by the electrical energy passing through the tube. However, the electrons could not stay in an excited state and had to get rid of the extra energy somehow. That energy was lost as specific colours of light. Since electrons were moving around the nucleus, Bohr imagined them as having orbits like the planets around our Sun. Because the hydrogen spectrum always had the exact same four colours, he further theorized that the electrons were jumping up and falling back down in specific distances or steps. When the electrons were excited, they would jump up to the next higher orbit. When they lost their energy, they would drop back to the original orbit. These orbits or **energy levels** were always a specific distance from the nucleus—there were no steps part way in between each energy level.

But why are there four colours in hydrogen's spectrum? Bohr explained this by saying that sometimes electrons could get so much energy that they would bump up two, three, or four energy levels. When they dropped back down to the first level they would give off exact amounts of energy—which would be detected as different colours of light.

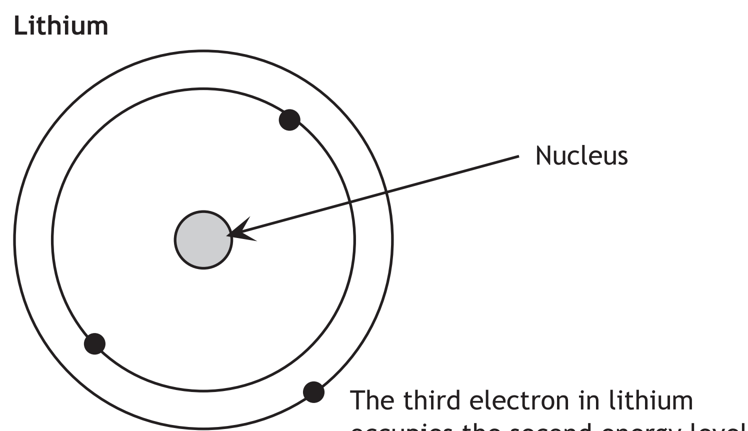
Further observations of other types of atoms with more electrons indicated that energy levels could only hold specific numbers of electrons. The first energy level, closest to the nucleus, could only have a maximum of two electrons. The second and third energy levels could only contain up to eight electrons each. Bohr stated that the orbits always filled up in order, from the first orbit outwards.

Using Bohr's model, hydrogen, which has one proton in the nucleus and one electron, resembles a solar system with one planet travelling around the Sun.

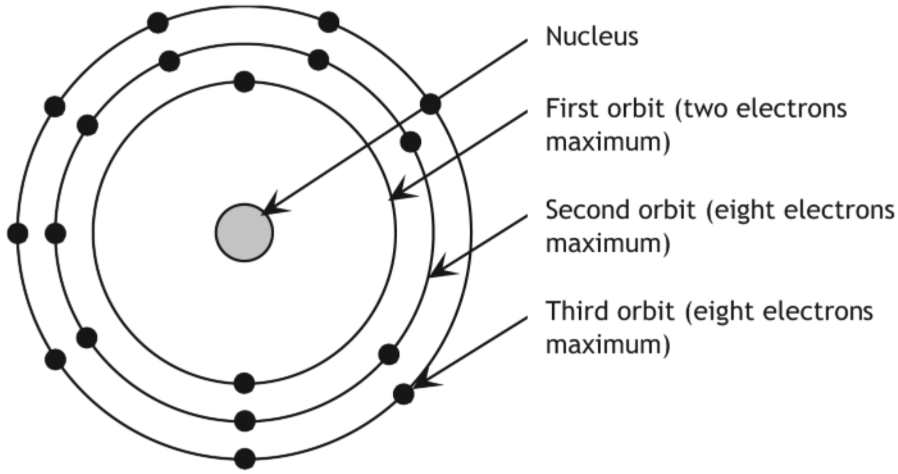


Hydrogen has one electron in the first energy level, and helium, the next element, has two electrons. The inner energy level cannot hold more than two electrons, so helium's inner energy level is considered full.

Lithium has three electrons. The first two electrons occupy the inner energy level and the third occupies the second energy level.

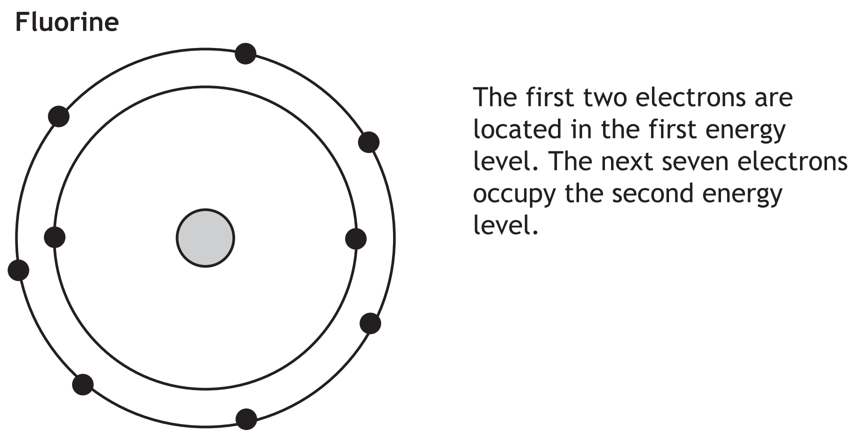


The second orbit is eventually filled when it has eight electrons. The diagram below shows the maximum number of electrons that can occupy each orbit.



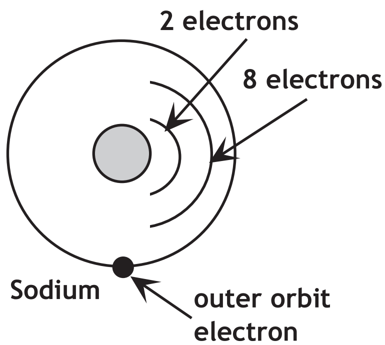
The electrons that occupy the outermost energy level in an atom are important in determining how an element will react with other molecules. These electrons in the outermost energy level are called **valence electrons**.

The Bohr model for fluorine is shown below. Fluorine has nine electrons. Note how they fill the energy levels around the nucleus.



Learning Activity 2.3: Atomic Orbitals

1. Neon follows fluorine and has 10 electrons in its orbits.
   a. How many electrons will neon have in its first orbit?
   b. How many electrons will neon have in its second orbit?
   c. The next element, sodium, has one more electron in its orbit. Where will that electron be located?
2. Draw Bohr atoms for the first 18 elements. When drawing Bohr atoms, you may draw filled orbits as partial lines with the number of electrons in that orbit written through the line. An example of this appears below.



3. Use the atoms you have drawn and arrange the names of the atoms in the table below according to the number of valence electrons in the outer energy level.

	1 Electron in e. level	2 Electrons in e. level	3 Electrons in e. level	4 Electrons in e. level	5 Electrons in e. level	6 Electrons in e. level	7 Electrons in e. level	8 Electrons in e. level
1st energy level								
2nd energy level								
3rd energy level								

Check the Learning Activity Answer Key found at the end of this module.

Summary

The Bohr model provides us with some insight regarding the structure of an atom in several ways. First, electrons are arranged in specific energy levels around the nucleus. Second, the higher the energy level, the further away from the nucleus the electrons are. Third, each orbit has a maximum number of electrons that it can hold. Last, the outermost electrons (or valence electrons) are important in helping to determine how an element will react with other materials.

Lesson 3: The Periodic Table

Lesson Focus

After completing this lesson, you will be able to

- ❑ identify properties of alkali metals, halogens, and noble gases
- ❑ compare and contrast the alkali metals, halogens, and the noble gases (i.e., their combining capacity and reactivity)
- ❑ predict the combining capacity of an element, based on its position in a periodic table

Key Words

- periodic law
- periodicity
- family
- alkali metals
- alkaline-earth metals
- chalcogens
- halogens
- noble gases
- period

Introduction

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 allow scientists to better predict the properties of elements and how elements would react with each other.

Dmitri Mendeleev, a Russian scientist and professor, began arranging the elements in rows according to their atomic mass and started a new row every time he came to an element that had similar characteristics to the first element in the row. He noticed that the columns that formed in this table contained elements that all had similar characteristics. He had discovered a repetition of the properties of elements which was called **periodicity**.

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?

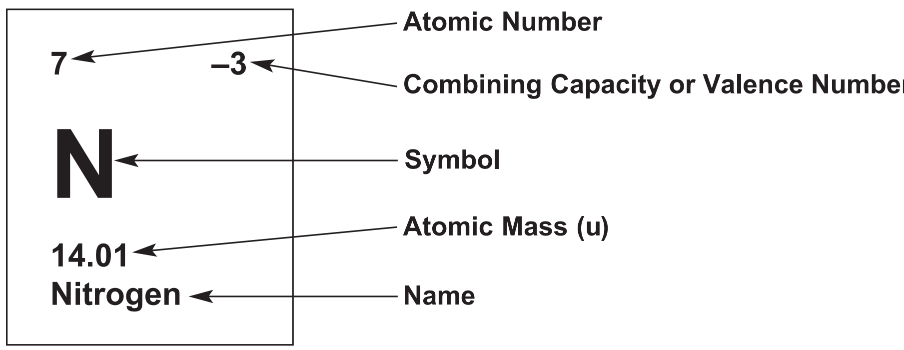
Henry Moseley, while doing some experiments with X-rays, discovered that the nucleus of each element had a unique positive charge. The positive charge was given the name atomic number. As a result, any element could be identified by its positive **atomic number**. When elements were arranged according 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**.

Design of the Periodic Table

As you read through the information in your notes, refer to the sample periodic table on the next page.

The periodic table is an important tool for chemists. It quickly determines some key facts about an element. A sample entry of an element in the periodic table is shown below.



The Periodic Table of the Elements

Key

6 +4 +2 } Combining capacity or Valence number

Atomic number → 6; Symbol → C; Carbon; 12.0 ↑ Atomic mass*

*Based on C^{12} = 12.00000

Alkali Metals (group 1); Alkaline-Earth Metals (group 2); Transition Metals (groups 3–12); Non-Metals (groups 13–17); Other Metals; Noble Gases (group 18)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 ±1 H Hydrogen 1.0																	2 He Helium 4.0
3 +1 Li Lithium 6.9	4 +2 Be Beryllium 9.0											5 +3 B Boron 10.8	6 +4 +2 C Carbon 12.0	7 −3 +5 N Nitrogen 14.0	8 −2 O Oxygen 16.0	9 −1 F Fluorine 19.0	10 Ne Neon 20.2
11 +1 Na Sodium 23.0	12 +2 Mg Magnesium 24.3											13 +3 Al Aluminum 27.0	14 +4 +2 Si Silicon 28.1	15 −3 P Phosphorus 31.0	16 −2 +4 S +6 Sulphur 32.1	17 −1 Cl Chlorine 35.5	18 Ar Argon 40.0
19 +1 K Potassium 39.1	20 +2 Ca Calcium 40.1	21 +3 Sc Scandium 45.0	22 +3 +4 Ti Titanium 47.9	23 +2 +5 V Vanadium 50.9	24 +2 +3 Cr +6 Chromium 52.0	25 +2 +7 Mn Manganese 54.9	26 +3 +2 Fe Iron 55.8	27 +2 +3 Co Cobalt 58.9	28 +2 +3 Ni Nickel 58.7	29 +1 +2 Cu Copper 63.5	30 +2 Zn Zinc 65.4	31 +3 Ga Gallium 69.7	32 +4 +2 Ge Germanium 72.6	33 −3 +5 As Arsenic 74.9	34 −2 +4 Se +6 Selenium 79.0	35 −1 Br Bromine 79.9	36 Kr Krypton 83.8
37 +1 Rb Rubidium 85.5	38 +2 Sr Strontium 87.6	39 +3 Y Yttrium 88.9	40 +4 Zr Zirconium 91.2	41 +5 +3 Nb Niobium 92.9	42 +6 +2 Mo Molybdenum 95.9	43 +7 +3 Tc Technetium (99)	44 +3 Ru Ruthenium 101.1	45 +3 Rh Rhodium 102.9	46 +2 +3 Pd +4 Palladium 106.4	47 +1 Ag Silver 107.9	48 +3 Cd Cadmium 112.4	49 +3 +1 In Indium 114.8	50 +2 +4 Sn Tin 118.7	51 −3 +5 Sb Antimony 121.8	52 −2 +4 Te +6 Tellurium 127.6	53 −1 I Iodine 126.9	54 Xe Xenon 131.3
55 +1 Cs Cesium 132.9	56 +2 Ba Barium 137.3	57 +3 La Lanthanum 138.9	72 +4 Hf Hafnium 178.5	73 +5 Ta Tantalum 180.9	74 +6 +2 W Tungsten 183.9	75 +7 +3 Re Rhenium 186.2	76 +2 +3 Os +4 Osmium 190.2	77 +2 +3 Ir +4 Iridium 192.2	78 +2 +4 Pt Platinum 195.1	79 +1 +3 Au Gold 197.0	80 +1 +2 Hg Mercury 200.6	81 +1 +3 Tl Thallium 204.4	82 +2 +4 Pb Lead 207.2	83 −3 +5 Bi Bismuth 209.0	84 ±2 +4 Po Polonium (209)	85 −1 At Astatine (210)	86 Rn Radon (222)
87 +1 Fr Francium (223)†	88 +2 Ra Radium (226)	89 +3 Ac Actinium (227)															

Inner Transition Metals

Series														
LANTHANIDE SERIES	58 +3 +4 Ce Cerium 140.1	59 +3 +4 Pr Praseodymium 140.9	60 +3 Nd Neodymium 144.2	61 +3 Pm Promethium (145)	62 +2 +3 Sm Samarium 150.4	63 +2 +3 Eu Europium 152.0	64 +3 Gd Gadolinium 157.3	65 +3 +4 Tb Terbium 158.9	66 +3 Dy Dysprosium 162.5	67 +3 Ho Holmium 164.9	68 +3 Er Erbium 167.3	69 −2 −3 Tm Thulium 168.9	70 −2 −3 Yb Ytterbium 173.0	71 −3 Lu Lutetium 175.0
ACTINIDE SERIES	90 +4 Th Thorium 232.0	91 +4 +5 Pa Protactinium (231)	92 +3 +4 U +5 +6 Uranium 238.0	93 +3 +4 Np +5 +6 Neptunium (244)	94 +3 +4 Pu +5 +6 Plutonium (244)	95 +3 +4 Am +5 +6 Americium (243)	96 +3 Cm Curium (247)	97 +3 +4 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)

†Masses in parentheses are the mass numbers of the most stable isotope.

Columns in the Periodic Table

A single column in the periodic table is called a **family**. A family contains elements that have similar but not identical properties. The alkali metals, alkaline-earth metals, chalcogens, halogens, and noble gases are all examples of families.

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 outermost energy level, so it is reactive. Almost all the hydrogen on Earth is combined with other materials or with itself.

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.

Alkali Metals

The alkali metal family occupies the first column in the periodic table and includes lithium (Li), sodium (Na), and potassium (K). Each element has one valence electron in its outer energy level. These metals are the most reactive metals in the periodic table because of the single electron in the outer energy level.

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 Earth in compounds like salt (sodium chloride).

Alkaline-Earth Metals

The alkaline-earth metals family is located in the second column of the periodic table. Alkaline-earth metals are less reactive than the alkali metal family because they have two valence electrons in their outer energy level. These atoms need to lose two electrons to become stable. Beryllium is the first member of the family, followed by magnesium, calcium, strontium, barium, and radium.

Chalcogens

The chalcogen (oxygen) family is located in the sixteenth column of the periodic table. The chalcogen family is slightly less reactive than the halogen family. They have six valence electrons in their outer energy level (that is, they are two electrons short of having a completely filled outer energy level). The first member of the chalcogen family is oxygen, followed by sulphur, selenium, tellurium, and polonium.

Halogens

The halogen (fluorine) family is the seventeenth family in the periodic table and includes fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At). The halogens have seven valence electrons, making them one electron short of filling their outermost energy level.

The halogens are the most reactive non-metals in the periodic table. In their natural state they are found combined with another element. Halogens such as fluorine and chlorine react with one atom of hydrogen to form HF and HCL respectively.

Noble Gases

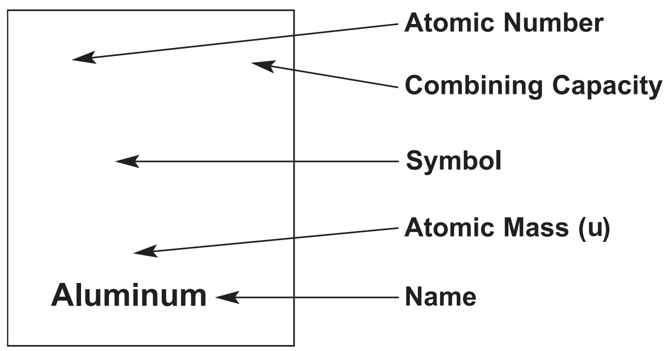
The noble gases (helium) family is the eighteenth family in the periodic table. It includes helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Ra). They are called noble gases because they do not generally form compounds with other elements. They are unreactive because their outer energy levels are completely filled with electrons. No natural compounds formed from these gases exist.

Rows in the Periodic Table

Rows in the periodic table are called **periods**. Elements found in the same period 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 the table, the elements change from metals (Li) to non-metals (C) and to gases (Ne).

Learning Activity 2.4: The Periodic Table

1. Complete the information for aluminum in the form below. Use a periodic table to find the information.



2. Look at the periodic table and your notes and note the number of valence electrons in each family. State the number of valence electrons for the families in the table shown below.

Family	Number of Valence Electrons
alkali metals	
alkaline-earth metals	
chalcogens	
halogens	
noble gases	

3. Describe where the following are found on the periodic table:
   a. metals
   b. non-metals
4. What would happen if fluorine
   a. gained an electron?
   b. lost an electron?
5. Make a hypothesis about the effect of lithium's losing an electron. Pay careful attention to the number of protons and electrons in this case.

continued

Learning Activity 2.4 (continued)

6. A new element has been discovered and all you know is that it is a halogen.
   a. Predict the number of electrons in its outer orbit.
   b. Predict its possible atomic number(s).
   c. On what do you base your predictions?
7. A new element has been discovered and all you know is that it is a noble gas.
   a. Predict the number of electrons in its outer orbit.
   b. Predict its possible atomic number(s).
   c. Explain your predictions.
8. Using the periodic table on page 22, answer the following questions.
   a. How many energy levels are there in the elements in the third row (period)?
   b. How many energy levels 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 energy levels the elements have in that period?
9. Why is hydrogen considered a family of one rather than an alkali metal?
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. atomic number?
       ii. number of protons?
       iii. number of electrons?

Check the Learning Activity Answer Key found at the end of this module.

Summary

The periodic table is a valuable tool for predicting the properties and behaviour of elements. In the next lesson, you will begin to study the formation of compounds.

The formation of compounds is determined by the valence electrons. The periodic table demonstrates how families have common numbers of valence electrons, allowing you to predict how elements will combine to form compounds.

Notes

Lesson 4: Electron Transfer and Ionic Compounds

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain why atoms combine in specific ratios to form compounds
- ❑ give examples of compounds that contain ionic bonds
- ❑ predict the kind of ion that results when electrons are added or removed
- ❑ use Bohr models to show how ionization and ionic bonding occur
- ❑ name binary compounds

Key Words

- ionic compound
- positive ions
- negative ions
- ionic bond
- ion

Introduction

Atoms have a tendency to combine and form new materials. Only about 100 different atoms combine to form the millions of materials that are found on Earth. In some ways, atoms behave like letters of the alphabet in that 26 letters combine to form the huge number of words in the English language.

This lesson shows you how elements combine to form ionic compounds.

A **bond** is a kind of glue that holds atoms together to form molecules. There are two types of bonds: **ionic bonds** and **covalent bonds**. We will use the next two lessons to study these two kinds of bonds and the molecules they form.

Ionic Bonds

Ionic bonds are formed when electrons are transferred from metal atoms to non-metal atoms. The metal atoms lose electrons to become positive ions, while the non-metal atoms gain electrons to become negative ions. The ions are then held together by the action of opposite charges in an ionic bond.

Ionic Compounds

As atoms combine together to form compounds, they do so in specific proportions (e.g., three chlorine atoms combine with every aluminum atom in aluminum chloride [$AlCl_3$]). The proportion of chlorine to aluminum is three to one in the compound. If there were one million molecules of the compound, there would be one million atoms of aluminum combining with three million atoms of chlorine.

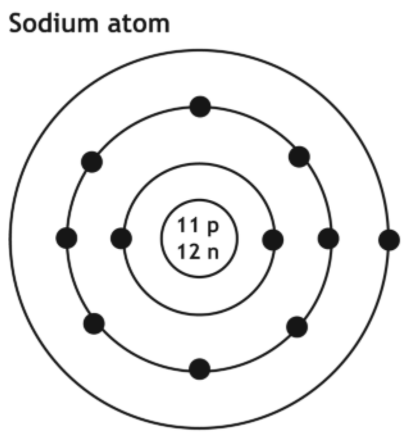
What Is an Ion?

An **ion** is a charged particle, created from an atom either losing or gaining electrons.

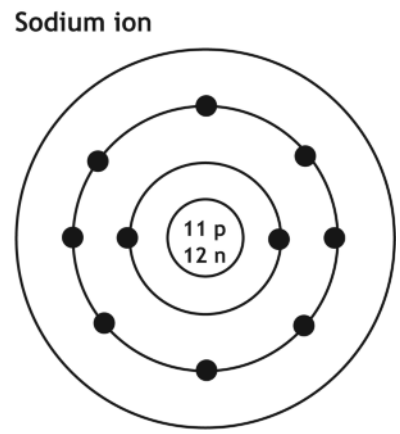
Positive Ions

Atoms contain electric charges—positively charged protons and negatively charged electrons. Atoms are considered neutral because the number of protons in the nucleus and the number of electrons around the nucleus are equal, resulting in a zero net charge for the atom. If one or more electrons are removed or lost, then the atom gains a net positive charge.

Sodium is an alkali metal located in the first family and second period of the periodic table. Sodium has a single electron in its outer energy level since it belongs to the alkali family. When sodium combines with a non-metal to form a compound, it will lose one electron.



11 positive charges in the atom.
11 negative charges in the atom.
0 net charge in the atom.



11 positive charges in the atom.
10 negative charges in the atom.
+1 net charge in the atom.

An electron is removed from the sodium atom, forming an ion.

If an electron is removed from sodium, the number of positive charges and negative charges are no longer balanced. Sodium has 11 protons and 11 electrons in a neutral atom; but there are 11 protons and 10 electrons when an electron is removed.

When an atom from the alkali family reacts with an atom from another element, it will give its valence electron to the other atom. In giving away its electron, the alkali metal atom has a filled outer energy level. Also, in giving away its electron, the atom becomes positively charged with a +1 charge.

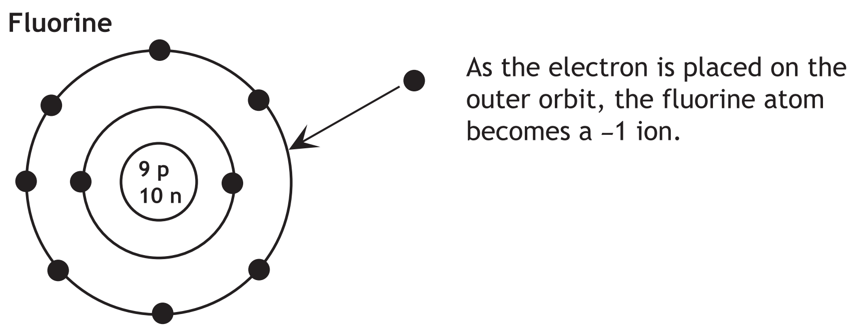
Atoms from the alkaline-earth family have two valence electrons. These atoms will give two valence electrons when combining with an atom from another element. After giving away the two valence electrons, the alkaline-earth metal atom has a **+2 charge**.

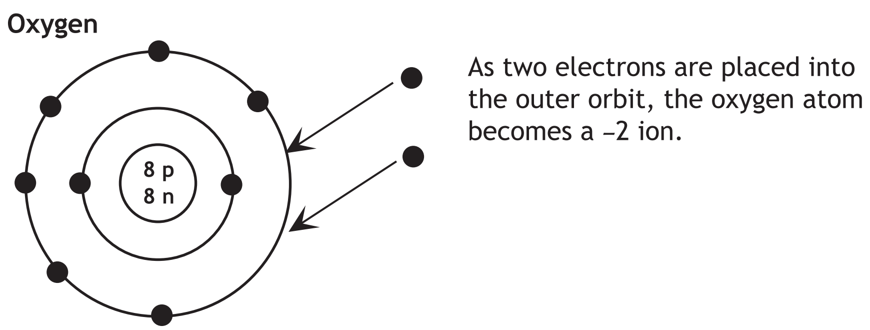
Alkali metals and alkaline-earth metals form positive ions when forming an ionic bond with another element.

Negative Ions

Negative ions are formed as a result of an atom gaining one or more electrons. The oxygen family and the halogen family willingly accept electrons in order to fill their outer energy levels. Once complete, they will resemble a noble gas. The halogens need only one electron to fill their outer energy levels, so they accept only one electron.

Once the extra electron is accepted, a negatively charged ion with a -1 charge is formed. The halogen family members all have the same combining capacity.



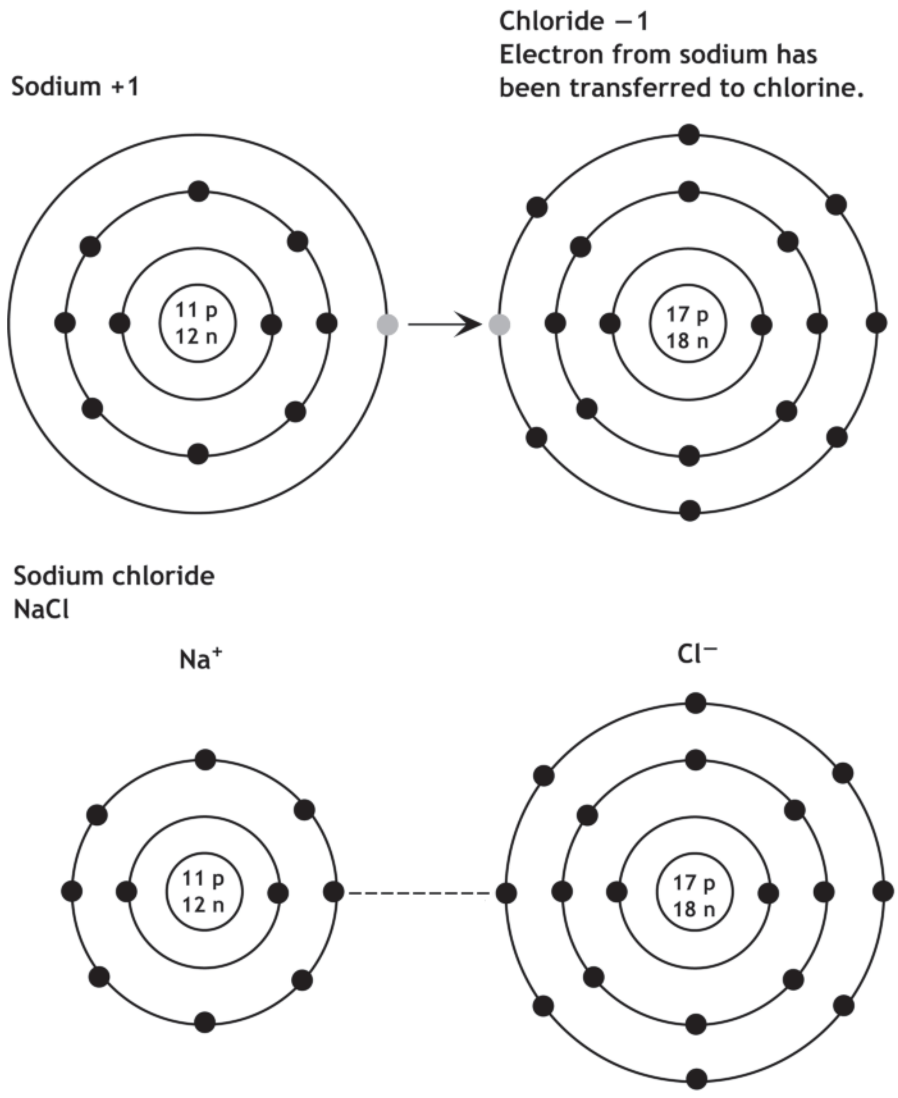


The chalcogen (oxygen) family needs two electrons to fill their outer energy levels. When this happens, -2 ions are formed. The chalcogen family members all have the same combining capacity of two.

When a positively charged ion comes near a negatively charged ion, they attract each other and form a bond called an **ionic bond**. An ionic bond will hold the two ions together to form a **compound**.

The formation of **compounds** often takes place violently when metals and non-metals are placed together. If a sample of sodium metal is placed in a container of chlorine gas, an explosive reaction takes place and the sodium combines with the chlorine to form sodium chloride. The Bohr model below provides an explanation for this reaction.

The sodium ion and chlorine ion are attracted because of their opposite charges and stick together to form salt. The "sticking together" is called an ionic bond. As extremely large numbers of sodium and chlorine atoms undergo this chemical reaction, they form a crystal of salt.



An ionic bond has formed between sodium and chlorine.

An **ionic compound** is formed when two ions are held together by an ionic bond. Some ionic compounds dissolve in water and form ionic solutions (e.g., when NaCl is dissolved in water it forms Na+ and the Cl– ions in solution).

Notice that when atoms combine to form ionic compounds, **they always gain or lose enough electrons to have a valence energy level like its closest noble gas neighbour.**

Generally, elements that have three or fewer electrons in the outer energy level are called **metals**. The strongest metallic properties are found in the first (or alkali) family of elements. The next strongest metallic properties are found in the alkaline-earth family. Metallic properties exist but in decreasing amounts through the boron family. Metals are conductors of heat and electricity and are shiny.

Elements that have five or more electrons in the outer energy level are classified as non-metals. Non-metals begin at the chalcogen (oxygen) family and end at the noble gas family. Non-metals are generally gases or brittle solids at room temperature.

There are exceptions to this general classification and some families have members that behave as both metals and non-metals (e.g., silicon). These elements are called **metalloids**. Many periodic tables have stair steps across families at the right side. These steps show the dividing line between metals and non-metals. The elements on the dividing line are metalloids. The periodic table on page 22 of this module illustrates this method of showing metals, non-metals, and metalloids.

Take time to review the ions formed by each family in the periodic table. Review the valence numbers found in your periodic table as well. Valence numbers tell you the number of electrons the atom will lose or gain as it forms a compound.

Family	Ions	Valence	Electrons
Alkali metals	+1	+1	1 lost
Alkaline-earth metals	+2	+2	2 lost
Boron	+3	+3	3 lost
Carbon	+4	+4	4 lost
Nitrogen	–3	–3	3 gained
Chalcogen	–2	–2	2 gained
Halogen	–1	–1	1 gained
Noble gas	0	0	0 gained

When ionic compounds are formed, **elements with a positive valence number will combine with elements having a negative valence number. In general terms, metals (families 1 and 2) combine with non-metals (families 16 and 17).** You can use the periodic table to predict what elements are likely to combine to form compounds.

Learning Activity 2.5: Ionic Compounds

Do the practice questions below to build your skill in writing formulas for ionic compounds.

1. Use Bohr model diagrams to illustrate the compounds formed from the following ions.

   a. Li^{+1} and Cl^{-1}

   b. Ca^{+2} and O^{-2}

   c. Na^{+1} and S^{-2}

   d. Al^{+3} and F^{-1}

Check the Learning Activity Answer Key found at the end of this module.

Summary

- Ionic compounds are formed when two ions with opposite charges are attracted to each other and remain together because of that attraction.
- An ion is formed when an electron is added or removed from an atom. To form a
  - positive ion, one or more electrons is removed
  - negative ion, one or more electrons is added
- Ionic bonds hold the ionic compound together.
- When an ionic bond is formed, the ions involved all have a valence energy level that appears like the closest noble gas.
- There are two basic types of materials shown in the periodic table: metals and non-metals. There are some elements that display the properties of both metals and non-metals. These elements are called metalloids.
- Each family in the periodic table contains elements with the same valence number.

Notes

Assignment 2.1: Atoms and Ionic Compounds (41 marks)

1. An atom of lead has an atomic number of 82 and an atomic mass of 207. *(1 mark x 6 = 6 marks)*

   a. How many protons are in one atom of lead? ________

   b. How many electrons are in one atom of lead? ________

   c. How many neutrons are in one atom of lead? ________

   d. How many protons are in one ion of Pb^{2+}? ________

   e. How many electrons are in one ion of Pb^{2+}? ________

   f. How many neutrons are in one ion of Pb^{2+}? ________

2. Several new elements have been discovered. Use the descriptions given to determine under which family each new element belongs: alkali metals, alkaline-earth metals, chalcogens, halogens, or noble gases. There may be more than one correct answer. *(1 mark x 4 = 4 marks)*

   a. The element is a solid at room temperature, and carries a single electron in its outer energy level.

   ____

   b. The element has six valence electrons in its outer energy level.

   ____

   c. The element is extremely reactive, and its valence energy level is one electron short of being completely filled.

   ____

   d. At room temperature, the element is found in the solid state.

   ____

continued

Assignment 2.1 (continued)

3. Draw a Bohr model of an oxygen atom. The diagram should indicate the location of the nucleus, and include the correct number of orbitals, each with the proper number of electrons. Indicate how many protons and neutrons are located in the nucleus. *(5 marks)*

4. How many ionic bonds are necessary to provide an alkaline-earth metal with a complete valence energy level if the negative ions are from the

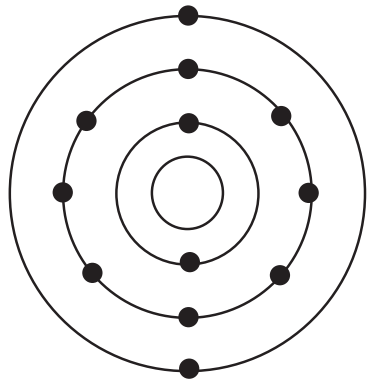
   a. halogen family? Explain your answer. *(3 marks)*

   b. chalcogen family? Explain your answer. *(3 marks)*

continued

Assignment 2.1 (continued)

5. Use the diagram below to answer the following questions.



a. Use the periodic table to name this element. *(1 mark)*

____

b. To which family does this element belong? *(1 mark)*

____

c. Would you classify this element as a metal or non-metal? Explain your choice. *(2 marks)*

____

____

____

d. How many electrons would you expect this element to gain/lose when it becomes an ion? *(1 mark)*

____

____

e. What is the charge of this element when it becomes an ion? *(1 mark)*

____

f. Would the element be more likely to combine with chlorine or lithium? Explain why. *(3 marks)*

____

____

____

continued

g. Draw a Bohr model of the ion that is normally formed from the atom in the diagram. Your drawing should indicate the location of the nucleus, and include the correct number of orbitals, each with the proper number of electrons. Indicate how many protons and neutrons are found in the nucleus. *(5 marks)*

6. Complete the following table. *(6 marks)*

Element	Number of Electrons Lost or Gained	Positive or Negative Ion	Charge on Ion
Sulfur			
Boron			
Calcium			
Chlorine			

Lesson 5: Electron Sharing and Covalent Bonds

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe a covalent bond
- ❑ state the differences between covalent and ionic bonds
- ❑ explain the octet rule
- ❑ use the Bohr model to illustrate the formation of covalent bonds and electron sharing
- ❑ explain the term *molecule*
- ❑ describe a diatomic molecule

Key Words

- octet rule
- covalent compound
- covalent bond
- molecule
- diatomic molecule
- valence electron

Introduction

Ionic compounds are formed when two atoms with opposite charges are attracted to each other and remain together because of that attraction. This occurs in order to complete the valence shell of each atom. There is one additional method for atoms to reach this "complete" form where valence shells are filled—covalent bonding. This lesson will introduce you to the means of covalent bonding, and explain which atoms are capable of this "electron sharing."

Covalent Bonds

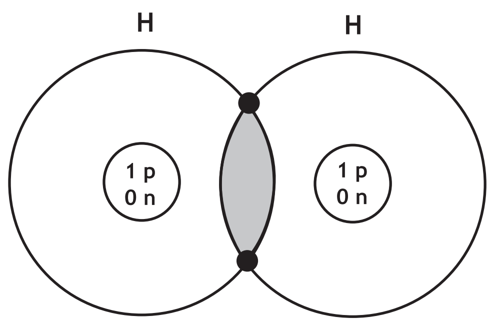
When two ions form **ionic bonds**, they **transfer** one or more electrons from a metal atom to a non-metal atom. As a result of the electron transfer, one ion has a positive charge (loses electrons) and one has a negative charge (gains electrons). An attraction exists between these ions, forming an ionic bond, holding them together as an ionic compound.

Many compounds, however, do not form ionic bonds. These compounds contain two or more non-metallic atoms. For example, CO_2 is made of two different non-metals, carbon and oxygen. These compounds are formed through the sharing of valence electrons. **A covalent bond is formed when two or more non-metallic atoms share valence electrons.**

Two hydrogen atoms form a covalent bond by sharing their electrons to produce a hydrogen molecule.

- A **molecule** is two or more atoms chemically combined.
- A molecule has different characteristic properties from the atoms that form it.

The Bohr model for hydrogen shown below illustrates a covalent bond.



Note: The electrons are shared in the outer orbits of both atoms. This covalent bond forms a molecule of hydrogen (H_2).

When two atoms of hydrogen come close to each other, the protons attract each other's electrons. The force is not strong enough to cause an electron transfer (ionic bond), but it is strong enough to force the electrons to travel among both of the atoms' orbits, spending most of the time in the overlap shown in the diagram, between the two nuclei. As a result, the two electrons are shared by both atoms. The hydrogen atom at the left "looks" at its orbit and "sees" two electrons; so does the one at the right. By sharing their electrons, both atoms are satisfied they have filled outer orbits.

The two hydrogen atoms form a **diatomic molecule** (two atoms sharing electrons to make a single molecule).

A list of diatomic molecules is shown below. Many of these molecules, which you recognize as gases, are important to life. The elements forming diatomic gases are unstable as single atoms and combine almost instantaneously to form stable molecules.

Name of Element	Symbol for One Atom of the Element	Formula for One Molecule
Hydrogen	H	H_2 (gas)
Nitrogen	N	N_2 (gas)
Oxygen	O	O_2 (gas)
Fluorine	F	F_2 (gas)
Chlorine	Cl	Cl_2 (gas)
Bromine	Br	Br_2 (liquid)
Iodine	I	I_2 (solid)

In each of the cases above, the outer energy levels of the atoms are filled with electrons. An energy level is filled when it contains all the electrons it can hold in that particular energy level. When an energy level is filled, it has the same number of electrons as an inert gas and becomes itself inert or unreactive.

Hydrogen has a filled first energy level when it shares a single electron with another element. This need for another electron makes hydrogen extremely reactive. By sharing an electron with another hydrogen atom, the energy level is filled and a hydrogen molecule is produced. Helium already has two electrons in its outer orbit and is stable. For this reason helium gas does not react with other elements.

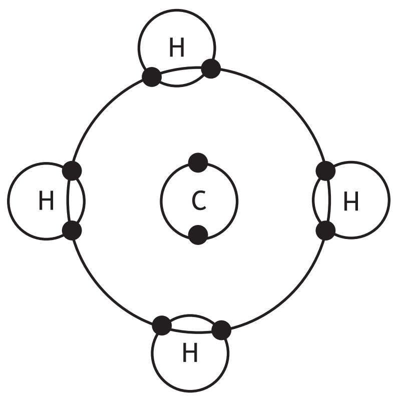
All other atoms need eight electrons to fill their second and third energy levels. A basic rule in chemistry is that an atom with eight electrons in its outer orbit is particularly stable. This need for eight electrons in a covalent bond is called the **octet rule**.

Covalent Compounds

Covalent compounds are formed when electrons are shared between non-metal atoms.

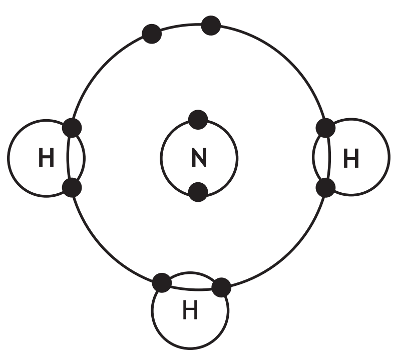
Overlapping circles on the outer orbit of a Bohr model atom illustrate how atoms can share electrons in a covalent bond. This way of representing covalent bonds is not completely correct but it is a good illustration.

a. methane CH_4



Notice that the formula for methane tells you that one carbon atom combines with four hydrogen atoms to form one molecule of methane.

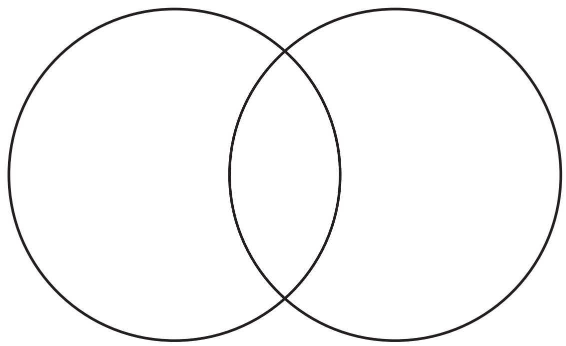
b. ammonia NH_3



Notice that the formula for ammonia tells you that one nitrogen atom combines with three hydrogen atoms to form one molecule of ammonia.

Learning Activity 2.6: Forming Covalent Bonds

1. Venn diagrams are concept maps used to compare and contrast two ideas. Each circle represents an idea, and its unique traits are written inside. The area where the circles overlap lists the traits held in common. Complete a Venn diagram showing the similarities and differences between ionic bonding and covalent bonding.



2. What is the octet rule?
3. What is a diatomic molecule?
4. What is the smallest unit of a covalent compound?
5. A list of pairs of atoms is shown below. Indicate whether each pair would form a compound using an ionic bond or a covalent bond.
   a. calcium and bromine
   b. hydrogen and oxygen
   c. carbon and oxygen
   d. lithium and oxygen
   e. phosphorus and chlorine

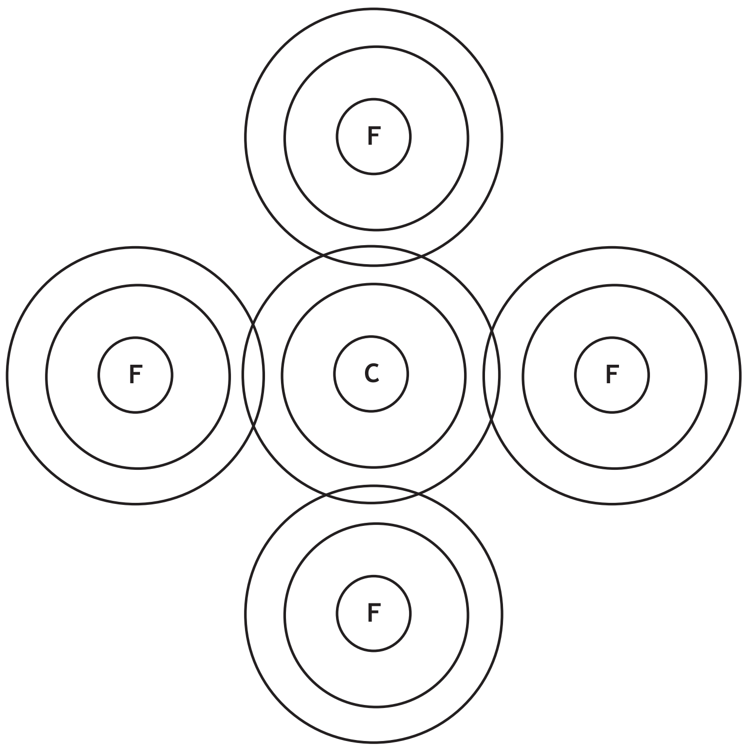
continued

Learning Activity 2.6 (continued)

6. Complete the drawings below. One atom of carbon is combining with four atoms of fluorine to form one molecule of a compound.

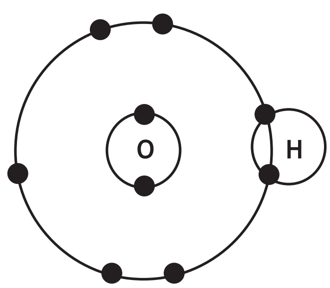
   a. What kind of bond is used to make the compound?

   b. Place the proper number of electrons in the atoms in their proper orbits.



7. Complete the following Bohr diagrams by drawing the remaining hydrogen atoms.

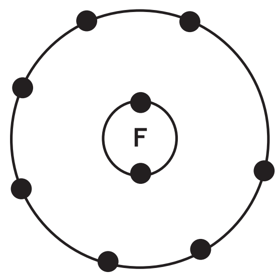
   a. water H_2O



continued

Learning Activity 2.6 (continued)

b. hydrogen fluoride HF



Check the Learning Activity Answer Key found at the end of this module.

Summary

- A covalent bond is formed between two non-metals that share electrons.
- The valence number or combining capacity on the periodic table is the number of electrons that the atom must share or transfer to produce a compound.
- Covalent compounds form bonds by sharing electrons. Ionic compounds form bonds by transferring electrons.
- The smallest particle formed by an atomic bond is a molecule.
- A molecule has different properties from the atoms from which it is formed (e.g., water has different properties from hydrogen and oxygen).
- The octet rule states that an atom having eight electrons in its outer orbit is stable and no longer reactive. When covalent or ionic bonds are formed, the octet rule is satisfied. An atom that has satisfied the octet rule has an outer orbit configuration similar to an inert noble gas. Hydrogen and helium are stable with just two electrons.
- The Bohr model can be used to illustrate the formation of covalent bonds. The outer orbits of the Bohr atoms involved in bonding overlap where the shared electrons are placed.

Notes

Lesson 6: Formulas and Names of Binary Ionic Compounds

Lesson Focus

After completing this lesson, you will be able to

- ❑ write formulas for binary ionic compounds
- ❑ name binary compounds

Key Words

- electron transfer
- binary compounds
- classical system of nomenclature
- Stock system
- IUPAC

Introduction

As of 2010, 112 unique elements have been catalogued and named. Of course, when these elements create bonds between each other, an entirely new molecule is created that requires a new name. That means, if we consider only molecules made up of only two atoms, that 12 544 names must be made! How can we keep track of all these possible combinations and give each molecule a meaningful name?

Fortunately, we have established a chemical language that can name every possible molecule, while telling us exactly what elements are within the molecule. In this lesson, you will learn how to use this naming system.

Writing Formulas for Ionic Compounds

The periodic table can be used to predict how elements combine to form compounds. You know that an element with a positive ion combines with an element with a negative ion to form an ionic compound. Combining capacity or valence numbers can be used to write the formula of an ionic compound.

For example, the alkaline-earth metals have a valence number of +2. Beryllium (Be^{+2}) and chlorine (Cl^{-1}) combine to form beryllium chloride ($BeCl_2$). The alkali family and the alkaline-earth family are both metals and form strong ionic bonds with the halogen family.

When writing correct formulas for these compounds, there are several rules to follow. Beryllium and chlorine will be used as examples.

- Write the symbol of the metallic element first. In the example, Be is written first. The non-metal, chlorine, is written second. $Be^{+2}Cl^{-1}$
- The overall charge on a compound is neutral. Combining Be (+2 charge) with Cl (-1 charge) results in a +1 charge overall.
- To make a neutral compound, multiply one or both atoms by numbers that result in an overall charge of 0.

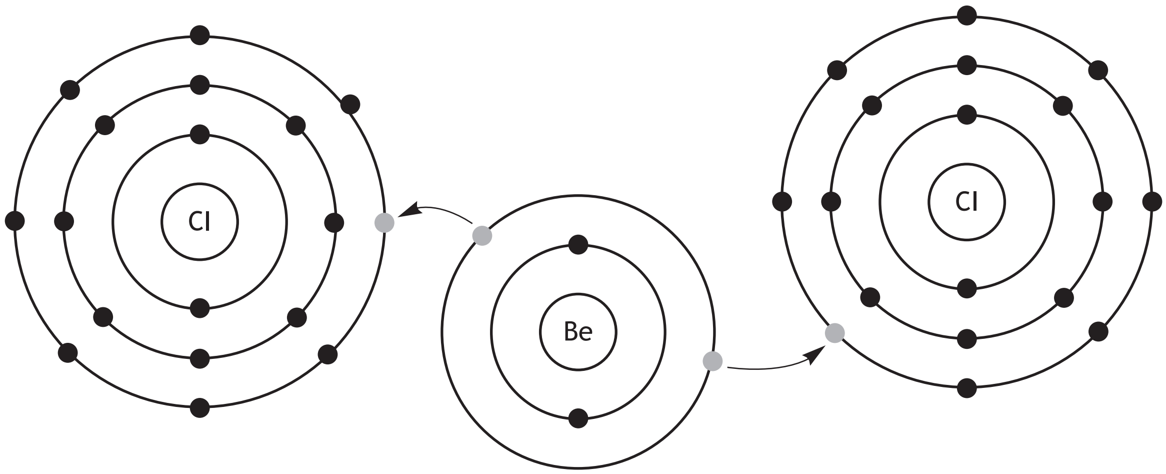
$$Be^{+2(x1)} = {}^{+2} \qquad Cl^{-1(x2)} = {}^{-2}$$

$$+2 + (-2) = 0$$

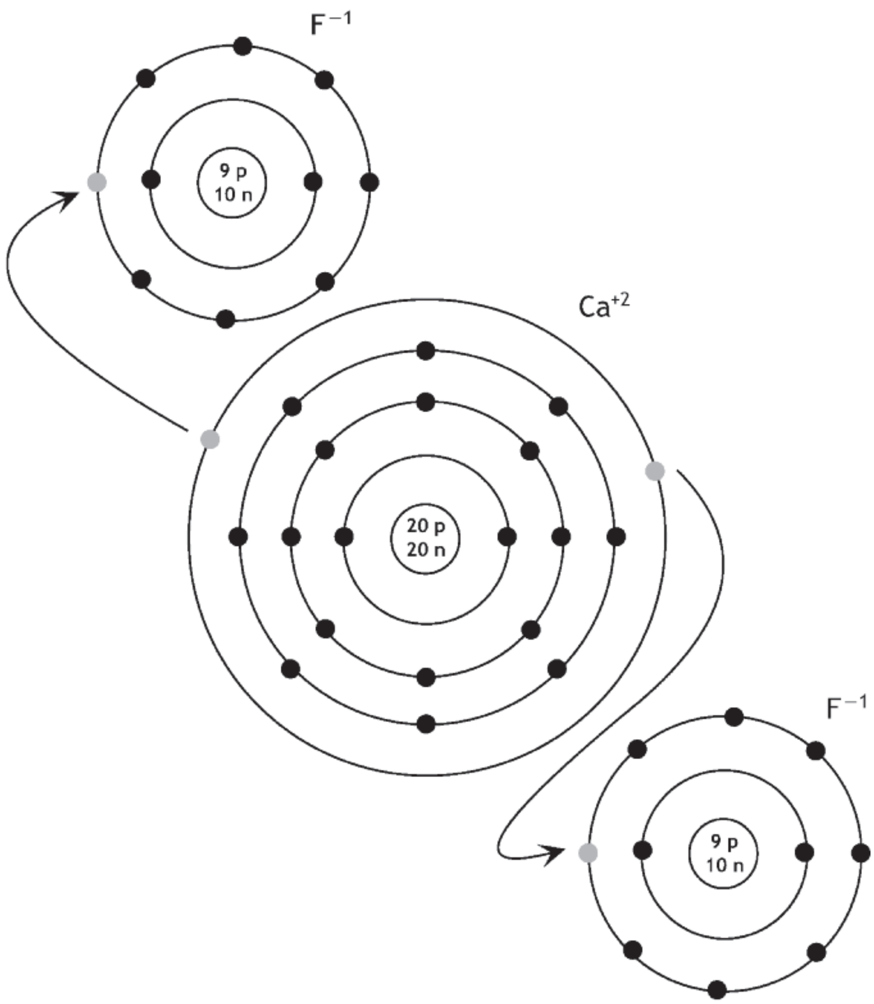
- Use the multiplier (1 for Be and 2 for Cl) as subscripts in the formula. If a subscript has a value of 1, leave it out. Notice that Be has no subscript in the example

$$x1 \rightarrow BeCl_2 \leftarrow x2$$

- Reduce the subscripts when necessary by the greatest common factor (e.g., when magnesium combines with sulfur, the formula might appear as Mg_2S_2, but it should be reduced to MgS by dividing both subscripts by 2).



The formation of an ionic bond can be illustrated using Bohr models. The example below shows the formation of calcium fluoride.



Naming Ionic Compounds

The compounds you have examined up to this point are formed by **two elements and are called binary compounds**. It is easy to name binary compounds, but you need to know some rules.

Until the eighteenth century, no system for naming compounds existed. Some compounds received common names based on their appearance or use (e.g., oil of vitriol and butter of arsenic, water, baking soda). When the same substance was given two names by different countries because of their different languages, it caused confusion. As scientists from many countries compared notes and used each other's work as building blocks to the next discovery, standardization became necessary.

As a general rule, the following two rules apply to naming ionic compounds:

- Name the positive ion first by writing the full name of the metallic element.
- Name the non-metal ion next by dropping the last syllable(s) from the name of the element and adding the suffix "ide."

  For example, reaction between sodium and chlorine forms sodium chloride, and the formula SrS is named strontium sulfide.

Classical System

In 1787, French chemist Guyton Morveau devised a systematic method for naming compounds. This system became known as the **classical system** of nomenclature. It used common Greek and Latin names, which chemists understood. The naming of compounds followed the method you have just learned.

Difficulties arose when a metal ion had more than one valence number. For example, two different ions have been identified for the element iron: Fe^{2+} and Fe^{3+}. The classical system identified the different valence numbers by using the endings "ous" and "ic" and "ite." A metallic ion with a name ending in "ous" had a lower valence number than a metallic ion ending in "ic." Iron having a valence number of two became ferrous and the iron with a valence number of three was called ferric. Ferrous chloride was written $Fe(Cl)_2$ and ferric chloride was written $Fe(Cl)_3$. A new problem arose, however, since the cuprous ion had a valence number of one and the cupric ion had a valence of two. Cuprous chloride was written CuCl and cupric chloride was written $Cu(Cl)_2$. So you see, the valence number represented by each suffix changed according to the element.

Stock System

During the 18th century, German chemist Alfred Stock developed a new system called the Stock system. In the Stock system, the “ous” and “ic” are replaced by Roman numerals representing the valence number of the atom. In this system, ferrous becomes Fe(II) and ferric becomes Fe(III). A table showing ions with more than one valence is shown below. The Stock system solved the “ous”–“ic” problem, as you can see in the examples below.

$Fe(Cl)_2$	Iron (II) chloride
$Fe(Cl)_3$	Iron (III) chloride
CuCl	Copper (I) chloride
$Cu(Cl)_2$	Copper (II) chloride

There is no confusion over what valence number a name is describing since the valence number of the metal ion is included in the name. Note the valence number of the metal can be determined from the number of non-metal ions. In the example, $Fe(Cl)_2 \rightarrow$ Iron (II) chloride there are two chlorines, indicating that the valence number of the metal Fe is 2.

You should use the Stock system only when the metal element in the compound has more than one charge, as shown in the table below.

Ion	Stock System	Classical System	Chloride
Cu^{+1}	Copper (I)	Cuprous	Copper (I) chloride
Cu^{+2}	Copper (II)	Cupric	Copper (II) chloride
Fe^{+2}	Iron (II)	Ferrous	Iron (II) chloride
Fe^{+3}	Iron (III)	Ferric	Iron (III) chloride
Sn^{+2}	Tin (II)	Stannous	Tin (II) chloride
Sn^{+4}	Tin (IV)	Stannic	Tin (III) chloride

Only a few of the elements with more than one valence number are listed, but it does illustrate how both systems work.

The non-metal ion always ends with the suffix "ide" when naming compounds. Oxygen becomes an oxide when forming a compound and chlorine becomes a chloride. These two examples are representative of all metal and non-metal compounds.

The naming of compounds is monitored and updated by the **International Union of Pure and Applied Chemistry (IUPAC)**. This group was founded by chemists whose first meeting occurred in 1921.

Learning Activity 2.7: Naming Compounds

1. Write formulas for the following compounds that are named using the Stock system.
   a. lead (IV) oxide
   b. iron (III) chloride
   c. manganese (II) bromide
   d. bismuth (V) fluoride
2. Name the following binary compounds.
   a. $CaBr_2$
   b. $HgCl_2$
   c. K_3P
   d. $CuCl_2$
   e. ZnS
3. Use Bohr atoms to illustrate the formation of the following compounds.
   a. beryllium fluoride
   b. lithium chloride

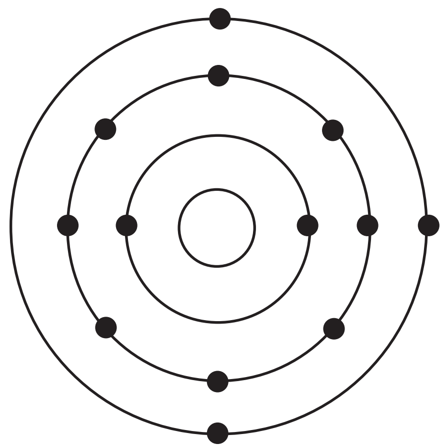
continued

Learning Activity 2.7 (continued)

4. Write formulas for compounds formed from the following sets of ions.
   a. Li^{+1} and Cl^{-1}
   b. Ca^{+2} and O^{-2}
   c. Na^{+1} and S^{-2}
   d. Al^{+3} and I^{-1}
   e. Ba^{+2} and F^{-1}
5. Write formulas for compounds formed from the following elements. (**Hint:** You will need to look up the combining capacities in the periodic table.)
   a. sodium and bromine
   b. potassium and oxygen
   c. aluminum and sulfur
   d. barium and chlorine
   e. lithium and oxygen
   f. silver and chlorine
6. Write formulas for the following compounds.
   a. potassium chloride
   b. sodium oxide
   c. calcium bromide
   d. magnesium oxide
   e. aluminum fluoride

continued

7. Use the diagram below to answer the following questions.



a. Use the periodic table to name this element.
b. To which family does this element belong?
c. Would you classify this element as a metal or non-metal?
d. How many electrons would you expect this element to lose when it becomes an ion?
e. What is the charge of this element when it becomes an ion?
f. Would this element be more likely to combine with chlorine or lithium?
g. Draw the ion that is normally formed from the atom depicted on the previous page.

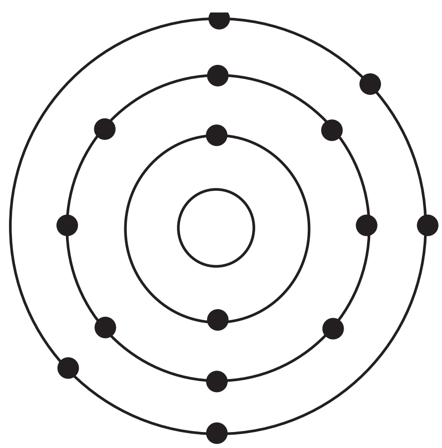
continued

Learning Activity 2.7 (continued)

8. Complete this table showing the properties of atoms forming ionic bonds.

Element	Number of Electrons Lost or Gained in an Ionic Bond	Positive or Negative Ion	Charge on Ion
Sulfur			
Boron			
Calcium			
Chlorine			

9. Use the Bohr diagram of the element below to answer the following questions.



a. Use the periodic table to name this element.

b. To which family does this element belong?

c. Would you classify this element as a metal or non-metal?

d. How many electrons would you expect this element to gain when it becomes an ion?

e. What is the charge of this element when it becomes an ion?

f. Would this element be more likely to combine with sodium or calcium?

Check the Learning Activity Answer Key found at the end of this module.

Summary

- Naming compounds became difficult in the eighteenth century as scientists isolated more elements and formed new compounds. Common names for compounds had no relationship to the chemical composition of the material because different countries used their own language to give different names to the same compound.
- The classical system developed by Guyton Morveau in 1787 began a systematic method for naming compounds. It used suffixes "ous," "ic," and "ite" to indicate the valence number of variable valence metal ions.
- The Stock system, named after Alfred Stock, changed the naming system to include the valence number in the name of the compound (e.g., copper [II] chloride indicates that copper has a valence of two in the compound).
- Chemical formulas are an essential part of studying about materials. Some things to remember about chemical formulas include the following:
  - A metal usually combines with a non-metal when forming ionic compounds.
  - The metal is named first and the non-metal is named second (e.g., when lithium combines with fluorine, the compound is called lithium fluoride).
  - The non-metal usually ends with an "ide" (e.g., $CaCl_2$ is called calcium chloride).
  - The valence number of one element is transferred to the other element when writing a formula.

Lesson 7: Formulas and Names for Covalent Compounds

Lesson Focus

After completing this lesson, you will be able to

- ❑ write formulas for covalent compounds
- ❑ name covalent compounds

Key Words

- covalent bond
- descriptive prefix

Introduction

This lesson will continue to review the chemical naming system, this time focusing on the names of covalent compounds, and their chemical formulas.

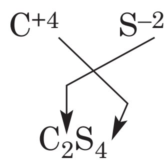
Writing Formulas for Covalent Compounds

Writing formulas for covalent compounds follows the same pattern as ionic compounds. When both covalent and ionic bonds are formed, they use electrons in the outer shells (valence electrons). **Covalent bonds** are formed when two non-metallic elements combine to form a compound.

1. Write both symbols, beginning with the element found closest to the left side of the periodic table. In this example, carbon (C) is further left than sulfur (S) and should be written first.

   C^{+4} S^{-2}

2. Exchange valence numbers and place them as subscripts, as shown in the diagram below.



3. Reduce the formula

   $C_2S_4 = C_1S_2$

4. The subscript "1" is dropped.

   CS_2 is the finished formula.

Naming Covalent Compounds

Covalent compounds are also named in the same way as ionic compounds (e.g., hydrogen fluoride is a predictable name for the compound formed from hydrogen and fluorine). The first non-metal element is named and the second non-metal element is named with the suffix "ide" added.

Some compounds also use common names. These names (e.g., water for H_2O) have become such a part of life that changing to dihydrogen oxide would be difficult. Other common names include ammonia for NH_3, and methane for CH_4.

Descriptive prefixes are used to identify molecules according to IUPAC rules. Sometimes elements combine in more than one way, so more descriptive names are used to help identify the compound (e.g., carbon monoxide and carbon dioxide). In carbon monoxide, carbon combines with one oxygen; in carbon dioxide, carbon combines with two oxygens. A list of prefixes and examples is shown below.

Mon(o)	(1) as in carbon monoxide (CO). This prefix is used only with the second element in the compound.
Di	(2) as in carbon disulfide (CS_2)
Tri	(3) as sulfur trioxide (SO_3)
Tetra	(4) as in carbon tetrachloride (CCl_4)
Pent(a)	(5) as in phosphorus pentoxide (P_2O_5)

When the second element is oxygen, the "o" in mono is dropped as is the "a" in tetra and penta.

Learning Activity 2.8: Names of Covalent Compounds

1. Write formulas for the following element pairs. Use the periodic table for reference.
   a. nitrogen – hydrogen
   b. carbon – chlorine
   c. nitrogen – bromine
   d. carbon – oxygen
   e. hydrogen – sulfur
2. Write names for
   a. PBr_3
   b. HF
   c. CF_4
   d. P_2O_3
3. Write formulas for the following compounds.
   a. phosphorus pentasulfide
   b. nitrogen monoxide
   c. carbon tetraiodide
   d. nitrogen dioxide
4. Write formulas for the following compounds.
   a. carbon tetrafluoride
   b. nitrogen monoxide
   c. dinitrogen tetroxide
   d. silicon disulfide

continued

Learning Activity 2.8 (continued)

5. Write the names for the following compounds.

   a. H_2S

   b. As_2O_3

   c. CBr_4

   d. OI_2

   e. N_2O_4

6. Why is it difficult to write correct formulas for the following compounds: chalk, gasoline, alcohol, and rust?

7. a. In what way are ionic and covalent bonds similar?

   b. In what ways are ionic and covalent bonds different?

8. What combining capacity would you expect for each of the following elements?

   a. bismuth

   b. boron

   c. silicon

   d. tellurium

   e. astatine

9. a. Is Cs_3N the formula of a covalent compound?

   b. Is C_3N_4 the formula of a covalent compound?

   c. How did you make your decision?

10. How can you determine whether a compound is a covalent compound?

continued

Learning Activity 2.8 (continued)

11. How many atoms of hydrogen combine with each of the following elements to form a covalent compound? When naming the compound, include both the chemical name and the common name, where applicable.

	Atoms of Hydrogen	Formula for Compound	Name of Compound
a. carbon			
b. boron			
c. nitrogen			
d. oxygen			

Check the Learning Activity Answer Key found at the end of this module.

Summary

- Chemical formulas for covalent compounds are written using the same rules as for ionic compounds.
- Covalent compounds are also named the same way that ionic compounds are named. Two changes to naming covalent compounds are
  - common names (e.g., water, ammonia, and methane)
  - descriptive prefixes used to help name compounds whose elements combine in several ways

Notes

Assignment 2.2: Atomic Bonding (31 marks)

1. Compare and contrast ionic bonding and covalent bonding. You may answer using a compare/contrast diagram. *(3 marks)*

2. Under what conditions will an atom not form any bonds with another atom? Give a specific example. *(2 marks)*

3. Indicate which of the following pairs of elements would form ionic bonds and which would form covalent bonds. *(1 mark x 5 = 5 marks)*

   a. beryllium and nitrogen ____________________
   b. sodium and fluorine ____________________
   c. silicon and bromine ____________________
   d. carbon and sulfur ____________________
   e. lithium and phosphorus ____________________

continued

Assignment 2.2 (continued)

4. Write the chemical formulas for the following binary compounds. *(1 mark x 3 = 3 marks)*
   a. potassium combined with chlorine ________________
   b. magnesium combined with bromine ________________
   c. calcium combined with oxygen ________________

5. Name the following compounds, and identify whether they are ionic or covalent. *(2 marks x 5 = 10 marks)*
   a. K_3P ______________________ ______________________
   b. HCl ______________________ ______________________
   c. CO_2 ______________________ ______________________
   d. $AlBr_3$ ______________________ ______________________
   e. NI_3 ______________________ ______________________

6. Write out the balanced formula for each pair of elements, and name the compound. *(2 marks x 4 = 8 marks)*
   a. Fe^{+2} and F^{-1} ______________________ ______________________
   b. Be^{+2} and S^{-2} ______________________ ______________________
   c. Fe^{+3} and O^{-2} ______________________ ______________________
   d. Li^{+} and P^{-3} ______________________ ______________________

Lesson 8: Using Molecular Formulas

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe the difference between element and compound and between atom and molecule
- ❑ use a chemical formula to determine which elements form a compound
- ❑ use the chemical formula to determine the proportions of each element in the compound
- ❑ use a chemical formula to determine the number of each type of atom in a compound

Key Words

- element
- compound
- atom
- molecule

Introduction

How many water molecules make up a single drop from a tap? How many individual atoms of hydrogen and oxygen would be within that drop? So far you have learned the rules for writing chemical formulas and naming compounds. Now, you will take a step back and look at the bigger picture: how do compounds group with one another to create the visible material of the world?

Composition of Compounds

Writing Elements and Compounds

Some substances are made of only 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 formed 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.

Elements combine to form **compounds** that are represented by chemical formulas. In the formula H_2O, the hydrogen [H] and oxygen [O] have combined to form water.

Sometimes groups of elements behave as single ions; these groups of elements are called **polyatomic ions**. You will use polyatomic ions later when you work with acids and bases.

How Chemical Formulas Help Us

They indicate the elements in a compound.

A chemical formula tells you what elements are used in the compound. The chemical formula $CuCl_2$ tells you that copper and chlorine make up copper (II) chloride.

They indicate the numbers of each element in a compound.

Chemical formulas indicate the number of atoms of each element in one molecule of the compound. In the formula H_2O, the subscript “2” to the right of H indicates that there are two atoms of hydrogen. There is no subscript to the right of “O”; therefore, there is only one oxygen atom.

Generally, the subscript following an element in a chemical formula indicates the number of atoms of that element in a single molecule.

Learning Activity 2.9: Elements and Compounds

1. Which of the following materials are a compound (C) and which are an element (E)?
    a. silver
    b. sugar
    c. propane
    d. steel
    e. molybdenum
    f. iron

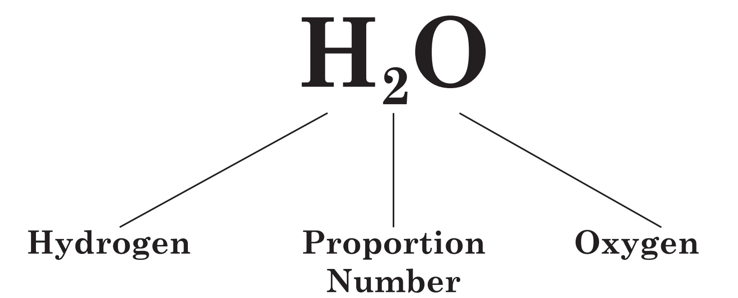
2. What elements are used in the following compounds?
    a. ZnO
    b. BeI_2
    c. Ga_2S_3
    d. $CnCl_2$
3. Determine the number of atoms of each element in one molecule of the following compounds.
    a. $AlCl_3$
    b. C_3H_8
    c. $C_{11}H_{22}O_{11}$

Check the Learning Activity Answer Key found at the end of this module.

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 two or more 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_2O] 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 sulfur using heat.
- 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 together.



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. To find the total number of atoms in a sample, you must take the molecular formula (H_2O) and multiply the subscripts by the number of atoms in the sample (10).

If you had three molecules of the compound carbon dioxide ($3CO_2$), we would have a total of 3 x 1 = 3 atoms of carbon and 3 x 2 = 6 atoms of oxygen.

Learning Activity 2.10: Identifying Elements

1. Determine the identity and number of atoms of each element in the given number of molecules or formula units described below.

Compound	Number of Molecules	Element Names	Number of Atoms of Each Element
$KHCO_3$	1 molecule $KHCO_3$		
$AlCl_3$	3 molecules $3AlCl_3$		
CBr_4	6 molecules $6CBr_4$		
H_2SO_4	5 molecules $5H_2SO_4$		
$C_{11}H_{22}O_{12}$	4 molecules $4C_{11}H_{22}O_{12}$		

continued

Learning Activity 2.10 (continued)

2. Locate the combining capacity for each family of elements.

Family Name	Combining Capacity
Alkali Metals (Family I)	
Alkaline-Earth Metals (Family II)	
Halogens	
Noble Gases	

3. Beside each of the formulas, list the elements in the compound and their relative proportions.

Formula **Elements and Proportions**

a. $BaSO_4$ **Ba 1 : S 1 : O 4** (example solution)

b. $NaHCO_3$

c. $CaSO_4$

d. $LiNO_3$

e. H_2SO_4

4. Using the compound CH_4, calculate the ratio of the number of atoms of hydrogen to the number of atoms of carbon.

5. Distinguish between an

a. element and a compound

b. atom and a molecule

Check the Learning Activity Answer Key found at the end of this module.

Summary

- Elements are the simplest form of any material. An element is a pure substance that cannot be further broken down by chemical reaction.
- A compound is made of two or more 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. The formula also indicates that for every atom of aluminum that has combined to form the compound, there are three atoms of chlorine).
- Periodic tables often list the valence number of the elements. The valence number indicates the number of electrons that are transferred or shared between atoms when they combine. Each family has the same valence numbers. Different families have different combining capacities.
- Chemical formulas also 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 9: Law of Conservation of Mass

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the relationship between balancing equations and the law of conservation of mass
- ❑ identify the physical state symbols used in chemical equations
- ❑ relate the conservation of mass to the conservation of atoms in chemical reactions

Key Words

- law of conservation of mass
- reactants
- products

Introduction

Chemical reactions are an important part of our daily lives. When you start a car engine, gasoline burns in a chemical reaction, producing the energy needed to drive down the street. When you (or the baker) make a cake, ingredients are mixed, a chemical reaction takes place, and carbon dioxide makes bubbles in the cake. If it were not for chemical reactions, all cakes would be rather heavy. In this lesson, you will learn how to represent chemical reactions using formula symbols, and you have a chance to carry out a chemical reaction experiment.

Chemical Reactions

Every chemical reaction obeys the law of conservation of mass. Antoine Lavoisier of France is given credit for discovering the law of conservation of mass around 1758. Lavoisier became convinced while performing experiments that the mass of the materials **before** the reaction took place (**reactants**) was always equal to the mass of the materials that were produced **after** the reaction took place (**products**). There hasn't been an experiment since that disputes his findings.

Notice that the terms *reactants* and *products* were used in describing the materials used in the reaction and the substances produced by the reaction respectively.

There are millions of reactions that take place every day. Some reactions are spectacular—fireworks, for example—and some reactions are considerably less so—iron rusting, for example. Every chemical reaction, however, can be described using a chemical equation.

Chemical Equations

Every chemical reaction can be described using a chemical equation. Chemical equations tell us two things:

1. the reactants (beginning materials) and the products (end materials) involved in the reaction.
2. the quantity of reactant atoms and molecules needed for the reaction to take place and the quantity of product atoms and molecules resulting from the reaction

A chemical equation is a simplified, short-hand set of symbols that describes a chemical reaction. Chemical equations allow scientists and engineers to understand in what proportions chemicals will combine and to predict how much product will be produced.

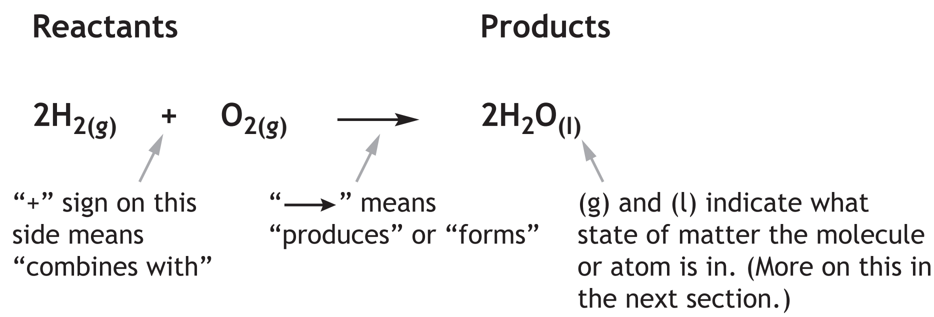
Here is an example of a simple chemical reaction:

Hydrogen gas and oxygen gas will, when ignited, form water droplets.

Chemists can simplify this by writing a **word equation**:

hydrogen gas + oxygen gas → liquid water

We know that hydrogen gas has a molecular formula of H_2 and oxygen gas has the formula of O_2 . Water is H_2O. We can give even more information in an even simpler form if we use these molecular formulae and a few more symbols:



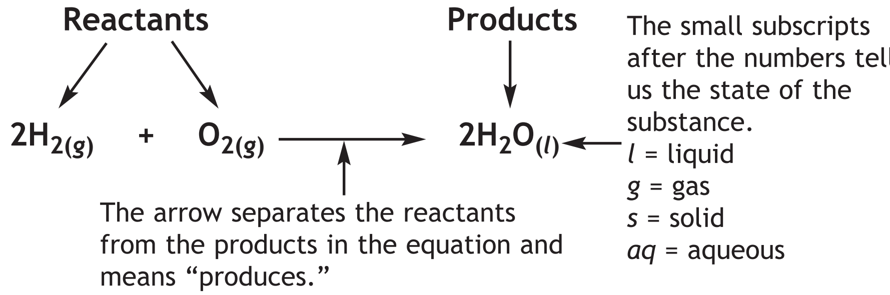
This is still not a proper chemical formula. If we count the atoms on each side of the arrow, we find that there are two oxygen atoms on the reactant side, but there is only one oxygen atom on the product side. There are two atoms of hydrogen on both sides. If we leave the chemical equation like this, we are actually saying that the amount of products and amount of reactants are not equal—there is one less oxygen atom on the product side. But the law of conservation of mass tells us that whenever a chemical reaction occurs the amount of products is always equal to the amount of reactants. This reaction is no different. So, to follow the law we must **balance the equation**. You will learn to do this in Lesson 10. For now, we'll provide you with the **balanced chemical equation**:

$2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{\,(l)}$

This is the proper chemical equation describing the reaction of hydrogen gas with oxygen gas to form water.

Chemical Equations and States of Matter

You have studied states of matter in previous grades. The three states of matter are solid, liquid, and gas. In chemistry, we add another state called **aqueous** for molecules. Aqueous molecules are ones that have been dissolved in water. For example, sodium chloride (salt) in a water solution would be called aqueous. An aqueous solution is identified since some chemical reactions will only take place when the reactants are dissolved in water.



We could describe the reaction above by saying "two molecules of hydrogen gas combine with one molecule of oxygen gas to produce two molecules of liquid water."

The equation would read "hydrogen gas plus oxygen gas produces liquid water."

Notice the large number 2 in front of hydrogen and water. These numbers are called **coefficients (kō•i•fish'•ints). The coefficients tell us the number of molecules or atoms of each reactant and product.** In this example, there are two molecules of hydrogen gas combining with one molecule of oxygen to produce two molecules of water. Now we can begin to see why the hydrogen tank is twice as large as the oxygen tank in the space shuttle.

You will now have an opportunity to carry out a chemical reaction of your own.

Learning Activity 2.11: Experiment : Law of Conservation of Mass

Note:

If you have access to a school lab facility, try to make arrangements with a teacher to conduct this investigation. If not, please use the sample data provided on page 79 to answer the questions in Learning Activity 2.11.

Purpose:

To determine experimentally whether mass is conserved during a chemical reaction.

Equipment/Materials:

- balance
- Erlenmeyer flask (125 mL)
- effervescent tablet—available at pharmacies and other stores
- balloon
- warm water (25 mL)

continued

Procedure:

Part A: Open System

1. Before the reaction, find the combined mass of the Erlenmeyer flask with 25 mL of water and one whole effervescent tablet. Record results.
2. Drop the effervescent tablet into the water, and mix gently until the reaction has stopped.
3. After the reaction, find the combined mass of the Erlenmeyer flask with water and effervescent tablet. Record results.

Part B: Closed System

1. Before the reaction, find the combined mass of the Erlenmeyer flask with 25 mL of water, one whole effervescent tablet, and the balloon. Record results.
2. Drop the effervescent tablet into the water and quickly place the balloon over the mouth of the Erlenmeyer flask. Mix gently until the balloon is inflated and the reaction has stopped.
3. After the reaction has stopped, find the combined mass of the Erlenmeyer flask with water, the effervescent tablet, and balloon still attached. Record results.

Data Collection:

If you completed this experiment, then fill in the following table with your data.

	Mass before Reaction	Mass after Reaction
Open System		
Closed System		

continued

Learning Activity 2.11 (continued)

If you did **not** complete this experiment, then use the following data.

	Mass before Reaction	Mass after Reaction
Open System	130 g	118 g
Closed System	145 g	144 g

Data Analysis:

Explain your results and draw conclusions about whether mass is conserved during all chemical reactions.

Now answer the following questions.

1. In Part A, how did the mass of the reactants and flask before the reaction compare to the mass of the reactants and flask after the reaction? Explain.
2. In Part B, how did the mass of the reactants and flask before the reaction compare to the mass of the reactants and flask after the reaction? Explain.
3. Did your results support the law of conservation of mass? Explain. If not, what sources of error might have affected your results?
4. A chemical reaction occurs when one or more substances react to produce one or more new substances. What happened to the reactants? Did they disappear? Were new atoms created when products were formed?
5. Can matter be created? destroyed? changed?
6. Do gases have a mass? If so, how can their mass be measured?

Check the Learning Activity Answer Key found at the end of this module.

Summary

Chemical reactions occur everywhere and at every minute of the day—even inside your own body. A chemical reaction can be illustrated by an equation: inputting reactants that interact to create a final product.

Notes

Lesson 10: Balancing Equations

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the difference between subscripts and coefficients
- ❑ balance skeleton equations by adding coefficients
- ❑ make sure that chemical equations have been correctly balanced and, if not, identify where the errors were made
- ❑ explain the difference between reactants and products

Key Words

- coefficient
- subscript
- word equation
- solid state
- liquid state
- gas state
- aqueous state

Introduction

Combining chemicals in order to produce a reaction is very similar to cooking and carpentry: if you do not have the proper amount of material to work with, your creation will be a disaster. Cooking recipes follow precise ratios of ingredients, and adding too much (or too little) of a certain sauce or spice could leave your food unbearably sour or salty. Similarly, a carpenter must be aware of how much lumber a project requires. Whether building a house, furniture, or just a bird feeder, skimping on nails or wood leaves you with a structurally weakened creation.

In the case of chemical reactions, it is important to know how much of each reactant is required to drive a reaction, and how much of the product you should expect to create. By understanding the law of conservation of mass, you can ensure that all your chemical experiments follow balanced equations and result in success.

Balancing Equations

The law of conservation of mass tells us that **every chemical equation must have an equal number of atoms of each element on each side of the equation.** This means atoms cannot be created or destroyed in a chemical reaction. Below, our sample equation shows four atoms of hydrogen gas (reactant) on the left side of the equation and four atoms of hydrogen forming water (product) on the right side of the equation. Similarly, there are two atoms of oxygen (reactant) on the left side of the equation and two atoms of oxygen forming water (product) on the right side of the equation.

Reactants → $2H_{2(g)}$, $O_{2(g)}$ — **Products** → $2H_2O_{(l)}$

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$$

$2H_{2(g)}$	$O_{2(g)}$	$2H_2O_{(l)}$
Four atoms of hydrogen	Two atoms of oxygen	Four atoms of hydrogen and two atoms of oxygen

As you balance equations, there are several rules to remember:

1. You **cannot change the formula** of any reactant or product to change the numbers of atoms. H_2O, for example, cannot be changed to H_4O or H_2O_2 in order to "add" atoms to the equation. This would change the molecule from water to an entirely different substance.

2. You **can only change the coefficients** in front of the reactants and products.

   a. Coefficients can be placed only in front of the formula, not somewhere inside it; that is, you can write $2H_2O$, but not H_22O.

   b. Coefficients apply to the whole molecule. $2H_2O$ means there are two molecules of H_2O, which, in turn, means there are four atoms of hydrogen and two atoms of oxygen in those two molecules. If no coefficient is shown in front of a molecule, it means the molecule has a coefficient of 1.

c. Note the difference between a **coefficient** and a **subscript**. A coefficient tells us the number of molecules in an equation and can be changed to balance an equation. A subscript tells us the number of atoms in a molecule and cannot be changed. The formula for water is H_2O. The subscript 2 following the H means there are two hydrogen atoms combining with one oxygen atom to form one water molecule and it cannot be changed.

There are some rules that you can use when you are given an unbalanced equation that needs to be balanced. We will use the unbalanced equation as the production of water as an example.

$$H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{(l)}$$

1. Determine the number of atoms required for each element in the reactants and products.

   In the example, there are two atoms of hydrogen and **two** atoms of oxygen on the left side of the equation. There are two atoms of hydrogen and one atom of oxygen on the right side of the equation.

   $$H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{(l)}$$

$H_{2(g)}$	$O_{2(g)}$	$H_2O_{(l)}$
2 atoms hydrogen	2 atoms oxygen	2 atoms hydrogen, 1 atom oxygen

2. If the numbers of atoms on both sides of the equation are equal at this point, the equation is already balanced and you are finished. In this example, they are not the same and you go to the next step.

3. Add coefficients to the formula to make both sides equal.

   In this example, there is one atom of oxygen in water. In order to make two atoms of oxygen, we can only place the coefficient 2 in front of the water molecule formula, as shown below:

   2 x 1 = 2 atoms of O

   $$H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$$

   2 x 2 = 4 atoms of H

   The formula now shows two molecules of water on the right side of the equation. This means there are 2 x 2 = 4 atoms of hydrogen and 2 x 1 = 2 atoms of oxygen on the right side of the equation.

There are already two atoms of oxygen on the left side of the equation, but to show four atoms of hydrogen, we must place the coefficient 2 in front of the hydrogen molecule, as shown below.

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$$

This is a balanced equation. You may have to use some trial and error in this step.

4. Inspect the equation and recalculate the numbers of atoms on both sides of the equation. If they are equal, the equation is balanced. If they are not equal, increase the individual coefficients until the equation is balanced.

Examples

1. $C + O_2 \longrightarrow CO_2$

   Calculate the number of atoms of each element on each side of the equation.

Reactants		**Products**	
Carbon	Oxygen	Carbon	Oxygen
1 atom	2 atoms	1 atom	2 atoms

   The equation is already balanced.

2. $HCl + MgBr_2 \longrightarrow MgCl_2 + HBr.$

   This is unbalanced.

   a. Calculate the number of atoms of each element on each side of the equation.

Reactants				**Products**			
H	Cl	Mg	Br	H	Cl	Mg	Br
1	1	1	2	1	2	1	1

   b. Chlorine and bromine are unbalanced. Begin by balancing bromine.

   To get two atoms of Br, place a coefficient 2 in front of the molecule.

   $HCl + MgBr_2 \longrightarrow MgCl_2 + 2HBr$

   Now there are two hydrogen atoms on the left side of the equation. To get two hydrogen atoms on the right side of the equation, place a coefficient of “2” in front of HCl.

c. Check the equation again to make certain the numbers of atoms on both sides of the equation are the same.

$$2HCl + MgBr_2 \longrightarrow MgCl_2 + 2HBr$$

Reactants				**Products**			
H	Cl	Mg	Br	H	Cl	Mg	Br
2	2	1	2	2	2	1	2

You can see the numbers of atoms on both sides of the equation are the same and the equation is balanced.

In addition to writing balanced equations, you will be able to describe a chemical reaction as a word equation. In order to state **word equations**, you will need to make use of the rules for naming compounds that you learned in Module 2, Lessons 6 and 7. In your description, include the state of the chemicals (if they are known) and the coefficients of each reactant and product. Use the example below as a model.

$$Al(s) + Cl_{2(g)} \longrightarrow AlCl_{3(s)} \text{ (unbalanced)}$$

$$2Al_{(s)} + 3Cl_{2(g)} \longrightarrow 2AlCl_{3(s)} \text{ (balanced)}$$

Once the equation is balanced, the word equation can be stated.

> **Two molecules of solid aluminum combine with three molecules of chlorine gas to produce two molecules of solid aluminum chloride.**

It is also possible to produce a chemical equation, knowing the word equation, by reversing the process shown above.

Learning Activity 2.12: Balancing Equations

1. Balance the following skeleton equations:

   a. $C + S \longrightarrow CS_2$

   b. $Al + Cl_2 \longrightarrow AlCl_3$

   c. $Ba + O_2 \longrightarrow BaO$

   d. $Na + O_2 \longrightarrow Na_2O$

   e. $B + O_2 \longrightarrow B_2O_3$

2. Write word equations for the equations in Question #1 after you have balanced them.

3. Translate the following word equations to balanced chemical equations.

   a. Sodium metal combines with chlorine gas to produce sodium chloride crystals.

   b. Solid magnesium reacts with hydrogen chloride to produce a magnesium chloride solution and hydrogen gas.

   c. Potassium iodide reacts with calcium sulfide to produce potassium sulfide and calcium iodide.

   d. Silver oxide decomposes to produce silver metal and oxygen gas.

4. Translate the following chemical equations to word equations.

   a. $Fe_{(s)} + CnS_{(aq)} \longrightarrow FeS_{(aq)} + Cn_{(g)}$

   b. $4Fe_{(s)} + 3O_{2(g)} \longrightarrow 2Fe_2O_{3(s)}$

   c. $BaF_{2(aq)} + 2LiBr_{(aq)} \longrightarrow BaBr_{2(aq)} + 2LiF_{(aq)}$

   d. $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$

   e. $2MgO_{(s)} \longrightarrow 2Mg_{(s)} + O_{2(g)}$

5. Briefly describe the four steps to balancing a chemical equation.

continued

Learning Activity 2.12 (continued)

6. What name is given to
   a. the materials present before a chemical reaction begins?
   b. the materials present after a chemical reaction has taken place?
7. What is the difference between a coefficient and a subscript?
8. Why can you change the value of a coefficient but not a subscript when balancing an equation?
9. What is meant when we say calcium chloride is in an aqueous state?

Check the Learning Activity Answer Key found at the end of this module.

Summary

Not every chemical reaction operates on a one-to-one basis. Reacting one molecule of each reactant does not always produce one molecule of product. Sometimes certain reactants need to be present in greater quantities. By understanding how to read a chemical equation and how to balance the elements that come "before" and "after" the reaction, you will ensure that all reactions proceed smoothly and successfully.

This is an important lesson not only for chemists, but for painters, chefs, carpenters, and anyone who does work requiring raw material: plan ahead, and make sure you have enough of your "ingredients" to work with.

Notes

Assignment 2.3: Conservation of Mass (23 marks)

1. What is the law of conservation of mass? How can you determine whether a written chemical reaction obeys this law? *(2 marks)*

____

____

____

2. Express the following statements as balanced equations. *(2 marks x 4 = 8 marks)*
   a. Aluminum metal combines with chlorine gas to form aluminum chloride.

   ____

   b. Sodium metal combines with oxygen gas to form sodium oxide.

   ____

   c. Hydrogen chloride and magnesium bromide are mixed together, resulting in magnesium chloride and hydrogen bromide.

   ____

   d. Solid iron (III) oxide mixes with hydrogen gas, producing iron and water.

   ____

3. Balance the following equations and express them in a word equation. *(2 marks x 4 = 8 marks)*
   a. $B + O_2 \rightarrow B_2O_3$

   ____

   ____

   b. $PCl_3 + S \rightarrow P_2S_3 + Cl_2$

   ____

   ____

continued

c. $CH_4 + O_2 \rightarrow CO_2 + H_2O$

____

____

d. $SnO_2 + F_2 \rightarrow SnF_4 + O_2$

____

____

4. Teri is performing an experiment to explore whether the law of conservation of mass is a reasonable thing to accept in practice. She combines 10 g of zinc metal with 20 mL of hydrogen chloride in an open beaker to produce zinc chloride, and heats the mixture over a Bunsen burner to speed up the reaction. After the reaction is complete, and she has allowed time for the glass to cool and the vapour to escape, she measures the product and finds there to be only 18 mL of liquid, when she calculated that there should be 21.4 mL.

   a. Write out the balanced formula of the chemical reaction. *(2 marks)*

   ____

   ____

   ____

   b. Has Teri disproved the law of conservation of mass because she did not have 21.4 mL of product as expected? Why or why not? *(2 marks)*

   ____

   ____

   ____

   ____

   ____

   c. How could Teri improve her experiment in the future? *(1 mark)*

   ____

   ____

   ____

   ____

LESSON 11: REACTION TYPES

Lesson Focus

After completing this lesson, you will be able to

- ❑ list the indicators of chemical change
- ❑ classify chemical reactions as synthesis, decomposition, single displacement, double displacement, or combustion
- ❑ list examples of the five types of chemical reactions
- ❑ discuss everyday uses of the five types of chemical reactions

Key Words

- synthesis reactions
- decomposition reactions
- single replacement reactions
- double replacement reactions
- combustion reactions

Introduction

In the last lesson, you learned how to write balanced equations that represent chemical reactions. In this lesson you will learn to identify different types of chemical reactions.

Types of Chemical Reactions

Scientists have identified five types of chemical reactions. We will look at each of the types in detail.

1. **Single Replacement Reactions**

   In single replacement reactions, one element replaces another element in a compound. There are two possible reactions.

   a. One positive ion replaces another.

   $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

   Note that the zinc and hydrogen are both positive ions when they form molecules.

   Note that hydrogen is diatomic. It is a good idea to learn the diatomic elements in order to know that they form a diatomic molecule in some chemical reactions.

> **"Hoffbrinkle"**
>
> A clever way of remembering lists of things is to use a pneumonic, which is a phrase or word that shortens the list.
>
> In chemistry, "Hoffbrinkle" is a pneumonic used to remember the atoms that naturally form diatomic molecules: H O F Br I N Cl (hydrogen, oxygen, bromine, iodine, nitrogen, and chlorine). Unless these atoms are dissolved in a solution, they will form pairs with themselves: H_2, O_2, Br_2, I_2, N_2 and Cl_2.
>
> HOFBrINCl

   b. One negative ion replaces another.

   $Cl_2 + 2NaBr \longrightarrow 2NaCl + Br_2$

   Single replacement reactions can be illustrated using the following general equation.

   $$\text{element} + \text{compound} \longrightarrow \text{element} + \text{compound}$$
   $$A + BC \longrightarrow B + AC$$

   Some practical examples of a single replacement reaction include:

   – placing aluminum foil in a solution of iron (III) nitrate
   – placing a copper wire in a silver nitrate solution

2. **Synthesis Reactions**

   Two or more simple elements or compounds combine to form a more complex compound in synthesis reactions.

   A sample reaction is shown below.

   $2Mg + O_2 \longrightarrow 2MgO$

   A practical illustration of a synthesis reaction is to place powdered zinc and powdered sulfur in a fume chamber and heat with a Bunsen burner.

   Another example of a synthesis reaction is the formation of acid rain. When cars or factories burn fossil fuels, leftover gases such as sulfur trioxide (SO_3) are released into the atmosphere. These fumes combine with water vapor in the air to produce strong acids.

   $SO_3 + H_2O \longrightarrow H_2SO_4$

   sulfur trioxide ⟶ sulfuric acid

   A synthesis reaction can be illustrated using the general equation shown below.

   two or more elements or compounds ⟶ compound

   $A + B \longrightarrow AB$

3. **Decomposition Reactions**

   During decomposition, one compound splits apart into two or more pieces. These pieces can be elements or simpler compounds.

   A sample reaction is shown below.

   $2HgO \longrightarrow 2Hg + O_2$

   A decomposition reaction can be illustrated using the general equation shown below.

   compound ⟶ two or more elements or compounds

   $AB \longrightarrow A + B$

   A practical example of decomposition occurs in the electrolysis of water when water is decomposed into hydrogen and oxygen. A test to determine the presence of oxygen is to place a smouldering stick in the gas. Since oxygen supports combustion, the stick will burst into flames. A test to determine the presence of hydrogen is to mix the gas with oxygen and place a burning stick into the gas mixture. An explosive combination of hydrogen and oxygen results. This test should be approached with extreme caution and only small samples should be tested.

4. **Double Replacement Reactions**

In a double replacement reaction, two molecules split up and exchange ion partners. A positive ion always pairs up with a negative ion.

A sample reaction is shown below.

$$FeS + 2HCl \longrightarrow FeCl_2 + H_2S$$

A practical illustration of a synthesis reaction is to add potassium iodide solution to lead (II) nitrate solution.

A double replacement reaction can be illustrated using the general equation shown below.

compound + compound ⟶ compound + compound

$$AC + BD \longrightarrow AD + BC$$

5. **Combustion Reactions**

In a combustion reaction, oxygen reacts with a compound containing carbon and hydrogen (a hydrocarbon), giving off a large amount of energy in the form of heat and light. Another way to refer to combustion is "burning."

A sample combustion reaction is shown below:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

All hydrocarbons combine with oxygen gas when they burn to produce water and carbon dioxide.

A practical illustration of a combustion reaction occurs when we light a candle or eat some food.

A combustion reaction can be illustrated using the general equation shown below.

hydrocarbon + oxygen ⟶ carbon dioxide + water

$$C_xH_y + O_2 \longrightarrow CO_2 + H_2O$$

Learning Activity 2.13: Types of Chemical Reactions

1. Balance the practice synthesis questions below.
   a. $Mg + O_2 \longrightarrow MgO$
   b. $H_2 + O_2 \longrightarrow H_2O$
   c. $K + Cl_2 \longrightarrow KCl$
   d. $Fe + O_2 \longrightarrow Fe_2O_3$
2. Balance the decomposition practice questions below.
   a. $H_2O \longrightarrow H_2 + O_2$
   b. $MgCl_2 \longrightarrow Mg + Cl_2$
   c. $FeS \longrightarrow Fe + S$
3. Balance the practice double replacement questions below.
   a. $BaF_2 + LiBr \longrightarrow BaBr_2 + LiF$
   b. $HCl + AlBr_3 \longrightarrow HBr + AlCl_3$
   c. $BeF_2 + Na_2O \longrightarrow BeO + NaF$
4. Balance the combustion practice problems below.
   a. $C_7H_6O_2 + O_2 \longrightarrow CO_2 + H_2O$
   b. $Al + O_2 \longrightarrow Al_2O_3$
   c. $C_3H_8 + O_2 \longrightarrow CO_2 + H_2O$
5. Balance the following equations:
   a. $Ca + AlCl_3 \longrightarrow CaCl_2 + Al$
   b. $Si + S_8 \longrightarrow Si_2S_4$
   c. $C_2H_5OH + O_2 \longrightarrow CO_2 + H_2O$
   d. $Cl_2 + NaBr \longrightarrow Br_2 + NaCl$
   e. $N_2 + H_2 \longrightarrow NH_3$

continued

Learning Activity 2.13 (continued)

6. Identify the type of reaction for each example below.

   a. $Fe_{(s)} + CuS_{(aq)} \longrightarrow FeS_{(aq)} + Cu_{(s)}$

   b. $4Fe_{(s)} + 3O_{2(g)} \longrightarrow 2Fe_2O_{3(s)}$

   c. $BaF_{2(aq)} + 2LiBr_{(aq)} \longrightarrow BaBr_{2(aq)} + 2LiF_{(aq)}$

   d. $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$

   e. $2MgO_{(s)} \longrightarrow 2Mg_{(s)} + O_{2(g)}$

7. Complete and balance the following equations.

   a. $C_8H_{8(l)} + O_{2(g)} \longrightarrow$ (combustion)

   b. $Al_{(s)} + I_{2(g)} \longrightarrow$ (synthesis)

   c. $BeF_{2(aq)} + K_2O_{(aq)} \longrightarrow$ (double replacement)

   d. $Cl_{2(g)} + NaBr_{(aq)} \longrightarrow$ (single replacement)

   e. $NaCl_{(l)} \longrightarrow$ (decomposition)

8. Balance each of the following equations by inserting the proper coefficients where needed.

   a. $Mg_{(s)} + O_{2(g)} \longrightarrow MgO_{(s)}$

   b. $HCl_{(aq)} + Zn_{(s)} \longrightarrow H_{2(g)} + ZnCl_{2(s)}$

   c. $C_{25}H_{52(s)} + O_{2(g)} \longrightarrow CO_{2(g)} + H_2O_{(l)}$

9. Classify each of the following reactions.

   a. $2Fe_{(s)} + O_{2(g)} \longrightarrow 2FeO_{(s)}$

   b. $Cl_{2(aq)} + 2KBr_{(aq)} \longrightarrow 2KCl_{(aq)} + Br_{2(aq)}$

   c. $2Ag_2O_{(s)} \longrightarrow 4Ag_{(s)} + O_{2(g)}$

   d. $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$

Check the Learning Activity Answer Key found at the end of this module.

Summary

There are five types of chemical reactions. Two compounds may either join together (synthesis) or exchange individual elements (double replacement); sometimes this exchange is one-sided (single replacement). A compound may also break apart into its component elements (decomposition). Finally, we recognize the reaction of hydrocarbons with oxygen gas (combustion).

Notes

Lesson 12: Acids and Bases

Lesson Focus

After completing this lesson, you will be able to

- ❑ compare and contrast acid and base properties
- ❑ identify a substance as an acid or base, using characteristics of acids and bases
- ❑ identify acids and bases, based on their reaction to an indicator
- ❑ identify acids and bases and their strengths, based on their pH
- ❑ identify acid/base colours of common indicators

Key Words

- acid
- base
- indicator
- pH
- neutralize
- neutral

Introduction

You have probably used acids and bases many times throughout each day, even going so far as to drink weak acids! In this chapter, you will learn about these two important categories of chemicals and their unique properties.

Common Acids and Bases

You have already experienced the sour taste of acids. Acidic lemon juice in water with a little honey has been used as a refreshing drink for centuries. We also like carbonated beverages that make use of carbonic acid. Pickles need vinegar (acetic acid) to prevent them from spoiling.

Acids are used in many industrial processes. Production of paper, steel, and many other products requires the use of acids. Sulfuric and hydrochloric acids are commonly used in such industrial processes.

Bases are important household chemicals used for cleaning and disinfecting. Bases are also used in hairdressing when a "permanent" change is needed to change straight hair to curly hair.

The names and formulas of some common acids and bases are shown below.

Acids		Polyatomic Ion
hydrochloric acid	HCl	—
sulfuric acid	H_2SO_4	SO_4^- (sulfate)
nitric acid	HNO_3	NO_3^- (nitrate)
Bases		
sodium hydroxide	$NaOH$	OH^- (hydroxide)
calcium hydroxide	$Ca(OH)_2$	OH^- (hydroxide)
ammonium hydroxide	NH_4OH	NH_4^+ (ammonium)

Notice that some acids and all bases make use of polyatomic ions in their formulas.

Notice that acids tend to have H (hydrogen) in their formula and bases often have OH (hydroxide) as the second component in their formula.

Characteristics of Acids and Bases

	Acids	Bases
1.	The term *acid* comes from the Latin word *acere*, meaning sour. Some common sour substances known since ancient times are lemon juice (citric acid), vinegar (acetic acid), and sour milk (lactic acid). Even aspirin (acetylsalicylic acid) tastes sour when chewed.	Bases all taste bitter. An example of a base is soap. Do not taste bases.
2.	In 1663, Robert Boyle noticed that an acid turns a blue vegetable dye called "litmus" to a red colour.	If enough base is added to the litmus that was turned red by an acid, it will turn back to a blue colour.

A substance that changes colour when added to an acid or base is called an indicator. In this case, litmus is an **indicator**. We often use paper containing the litmus dye as an indicator.

There are many different types of indicators available. The table below gives you a brief list of the most common indicators, and their colour reactions to acids and bases.

Indicator	Acid	Base
Litmus	red	blue
Phenolphthalein	colourless	pink
Methyl Orange	orange	yellow
Bromothymol Blue	light yellow	blue

3. An acid and a base, when combined, will **neutralize** each other; that is, acids will lose their acid properties and bases will lose their base properties. When acids and bases are added to each other, the products always include a salt and water.

4. An electric current will pass through acids.	An electric current will pass through bases.
5. Many metals will react easily with an acid and produce hydrogen gas. $Ba + HCl_{(aq)} \rightarrow BaCl_2 + H_2$ (hydrogen gas)	Bases will not react with zinc.

6. Acids reacting with carbonates and bicarbonates will give off carbon dioxide gas.

$$HCl + KHCO_3 \longrightarrow CO_2 + H_2O + KCl$$

($KHCO_3$: potassium bicarbonate; CO_2: carbon dioxide gas)

7. Bases feel slippery. The reason for the slippery feel comes from a base's ability to dissolve oils and fatty acids in your skin, reducing the friction between your fingers as you rub them together. Bases destroy protein. Most animal material contains protein, making bases dangerous to handle. Extreme care should be taken whenever you handle a base.

Measuring the Strength of Acids and Bases—pH

The strength of an acid or a base is measured using a scale called pH.

The table below shows the range of pH values for acids and bases.

pH 0–6.9	Measures the strength of acid where a smaller number equals stronger acid and a larger number equals weaker acid
pH 7 (water)	**Neutral**—neither acid nor base
pH 7.1–14	Measures the strength of base where smaller number equals weaker base and larger number equals stronger base

A List of Some Common Acids and Bases and Their Approximate pH Values

Acid or Base	pH
Stomach fluid	1.7 Note the strength of the acid in stomach fluid. How can our stomach withstand the effect of such a strong acid? The lining is made of a material capable of resisting the acid.
Lemon juice	2.6
Vinegar	2.8
Soft drinks	3.0
Apples	3.1
Grapefruit	3.1
Oranges	3.5
Tomatoes	4.5
Black coffee	5.1
Saliva	5.1–5.7
Milk	6.5
Rainwater	slightly less than 7 Rainwater has become acidic.
Pure water	7
Blood	7.4
Eggs	7.8
Sea water	7.8
Milk of Magnesia	9
Household ammonia	11
Lye (NaOH)	14 Household lye is a very strong base and must be handled carefully.

You will now have an opportunity to carry out some investigative work into acids and bases.

Learning Activity 2.14: Experiment: Acids and Bases

Once again, since supplies or equipment might not be available, these experiments are optional. If you are attending school, ask a teacher whether this experiment can be done in the science lab.

After you have completed the tables, answer the questions carefully and thoughtfully.

Experiment: Properties of Acids and Bases

Purpose:

1. To classify substances as acids or bases, using their characteristic properties.
2. To determine the pH values of the acids and bases used.
3. To examine the reactivity of acids with metals.

Equipment/Materials:

- safety goggles
- red and blue litmus paper
- test tubes and test-tube racks
- indicators (universal indicator, phenolphthalein, bromothymol blue)
- pH metre or pH test paper
- eyedroppers
- microtray
- samples of acids and bases (milk of magnesia, ammonia window cleaner, vinegar, lemon juice, tomato juice, drain cleaner, carbonated drinks, shampoo, black coffee, laundry detergent, milk, salt water, tap water, baking soda, apples)
- samples of metals (copper, zinc, iron, magnesium)
- hydrochloric acid (6M), acetic acid (6M), sodium hydroxide (0.5M), calcium hydroxide (0.5M) (Note: M is the molarity or concentration of substance dissolved in the liquid.)

continued

Procedure:

Part A: Effects of Acids and Bases on Indicators

1. Place five drops of each of the following into the wells of a microtray: 6M hydrochloric acid, 6M acetic acid, 0.5M sodium hydroxide, and 0.5M calcium hydroxide.
2. Using a different piece of clean dry red litmus paper for each of the solutions, dip the end of a piece of red litmus paper into each solution. Record results in a data table.
3. Repeat step 2 using blue litmus paper. Record results in a data table.

Part B: Determine the pH Range of a Substance

1. Use the bromothymol, phenolphthalein, and universal indicators to measure the pH of the samples.
2. Add two drops of the bromothymol indicator to each sample from part A. Record your observations in a data table. Wash the microtray and repeat for phenolphthalein and universal indicator.
3. Confirm your results by retesting each sample with a pH meter or pH test paper.

Part C: Determine the Reactivity of Acids with Metals

1. Place a small sample of each metal to be tested in the different wells of a clean, dry microtray.
2. Use an eyedropper to add five drops of the hydrochloric acid onto each sample of metal. Note any signs of chemical change and record your observations in a data table. Repeat, using the acetic acid.

Part D: Determine the Acidity and Basicity of Household Substances

1. In different wells in your microtray, add five drops of any six of the following: vinegar, lemon juice, tomato juice, milk, household ammonia, cola, Milk of Magnesia, window cleaner, drain cleaner, shampoo, salt water, tap water.
2. Test each substance as you did in part A, using red and blue litmus paper.

continued

3. Test each substance as you did in part B, using indicators and pH paper.
4. Record the results in the data table.

Caution

Many household cleaners and hydrochloric acid solution(s) are corrosive or caustic. Any spills on the skin, in the eyes, or on clothing should be washed immediately with cold water. Report any spills to the teacher.

Data Collection:

Part A

Sample	Reaction with RED Litmus Paper	Reaction with BLUE Litmus Paper
Hydrochloric acid		
Acetic acid		
Sodium hydroxide		
Calcium hydroxide		

Part B

Sample	Bromothymol Blue	Phenolphthalein	Universal Indicator
Hydrochloric acid			
Acetic acid			
Sodium hydroxide			
Calcium hydroxide			

continued

Learning Activity 2.14 (continued)

Part C

Sample	Reaction with Hydrochloric Acid	Reaction with Acetic Acid
Zinc		
Magnesium		
Iron		
Copper		

Part D

Household Substances	Red Litmus Paper	Blue Litmus Paper	pH Paper	Bromothymol Blue	Phenolphthalein	Universal Indicator

continued

Learning Activity 2.14 (continued)

Data Analysis

Complete the tables below.

Tests	Acid Properties	Base Properties
Red litmus paper		
Blue litmus paper		
pH paper		
Bromothymol blue		
Phenolphthalein		
Universal indicator		
Reaction with a metal		

Household Sample	pH Value	Acid or Base

continued

Learning Activity 2.14 (continued)

1. Can either red or blue litmus paper be used to identify acids? Explain.
2. How accurate are indicators for measuring pH?
3. What signs of chemical change were observed when acids were placed on metals?
4. Did all metals react similarly? Explain.
5. List the general properties of acids and bases.
6. Which of the household substances are acidic? Which are almost neutral? Which are basic?

Check the Learning Activity Answer Key found at the end of this module.

Learning Activity 2.15: Classifying Acids and Bases

1. State whether the liquids in the following examples illustrate an acid (A) or a base (B).
   a. A liquid is added to zinc and a gas is produced.
   b. A liquid feels slippery between your fingers.
   c. You taste a beverage and it has a pleasant, sour taste.
   d. A hairdresser adds a liquid to someone's hair to give it a long-lasting curl.
   e. A liquid is added to colourless phenolphthalein, causing it to turn pink.

continued

Learning Activity 2.15 (continued)

f. A liquid is added to sodium carbonate and a gas is released. The gas will put out a burning splint.

g. A liquid turns blue litmus paper red.

2. Use the pH values described below to determine whether the substance is neutral, a weak or strong acid, or a weak or strong base.

   a. pH = 12

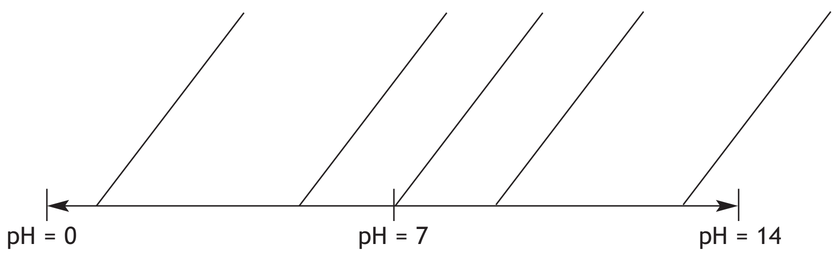
   b. pH = 7

   c. pH = 6

   d. pH = 9

   e. pH = 2

3. Label the line below with the following terms: *strong acid*, *strong base*, *weak acid*, *weak base*, *neutral*



4. Compare and contrast acids and bases.

   a. How are acids and bases similar?

   b. How are acids and bases different?

continued

Learning Activity 2.15 (continued)

5. Use the list of acids and bases below to answer the question. Place the formulas of the acids under the heading "Acid" and the formulas for bases under the heading "Base." If it is not an acid or a base, do not place it under either heading.

NH_4OH	KCl	H_2SO_4	$Mg(OH)_2$	$AlCl_3$	HCl
H_2CO_3	KOH	HNO_3	H_2O	HBr	$Al(OH)_3$

Acid	**Base**

6. State whether the following situations involve an acid or a base.
   a. It is added to a base. The products are salt and water.
   b. It is added to an active metal and a gas is produced.
   c. It is used as a household cleanser.
   d. It is used to make soft drinks.
   e. It tastes sour.
   f. It is part of stomach fluids.
   g. It tastes bitter.

continued

Learning Activity 2.15 (continued)

7. If you decided you wanted to drink the following, would you be drinking an acid or a base?

   a. milk

   b. lemonade

   c. orange juice

   d. Milk of Magnesia

8. Your mother asks you to bake a cake. She tells you to not forget the baking soda ($NaHCO_3$) and the lemon juice. The reaction is shown below.

   $NaHCO_3$ + lemon juice $\longrightarrow$ sodium compound + H_2O + CO_2

   a. Is lemon juice an acid or a base?

   b. Why is the lemon juice added to the sodium bicarbonate (baking soda)?

   c. What do you think carbon dioxide has to do with how "light" the cake is?

Check the Learning Activity Answer Key found at the end of this module.

Summary

- Acids are sour in taste, turn blue litmus to a red colour, and will react easily with metals to produce hydrogen gas. Acids will react with carbonates and give off carbon dioxide.
- Bases are bitter in taste, turn red litmus to a blue colour, and do not react with zinc. Bases are slippery to touch.
- When an acid and base are combined, they will neutralize each other, leaving water and a salt as products of the reaction.
- Both acids and bases can conduct an electrical current.
- The strength of acids and bases are measured using the pH scale. Acids have a pH reading between 0 and 6.9, and bases have a pH reading between 7.1 and 14. Substances with a pH of 7 are neither acids nor bases.

Assignment 2.4: Chemical Reactions (35 marks)

1. Identify the type of reaction occurring and balance the equation. *(2 marks x 5 = 10 marks)*

   a. $HgO \rightarrow Hg + O$

   b. $C_2H_2 + O_2 \rightarrow CO_2 + H_2O$

   c. $Al + ZnCl_2 \rightarrow AlCl_3 + Zn$

   d. $Cu + S \rightarrow Cu_2S$

   e. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

2. Complete and balance the following equations. *(2 marks x 5 = 10 marks)*

   a. $MgO \rightarrow$ (decomposition)

   b. $LiCl + Mg \rightarrow$ (single replacement)

   c. $C_3H_8 + O_2 \rightarrow$ (combustion)

   d. $NaBr + KI \rightarrow$ (double replacement)

continued

Assignment 2.4 (continued)

e. $Ca^{+2} + F^- \rightarrow$ (synthesis)

____

3. Several unknown compounds have been discovered. Based on their given properties, decide whether each is an acid or a base.
(1 mark x 6 = 6 marks)

a. Compound A turns red litmus paper blue.

____

b. Compound B is a solid that can conduct an electric current. When placed in an aqueous solution with zinc metal, there is no observed reaction.

____

c. Compound C is placed in a solution of sodium bicarbonate ($NaHCO_3$). The mixture begins to bubble vigorously and release carbon dioxide.

____

d. Compound D is to be placed in a solution of phenolphthalein indicator, but it is so slippery that no one can get a proper grip on it, and the experiment is abandoned.

____

e. A less-than-bright lab assistant decides to drink Compound E. When you visit him in the hospital after having his stomach pumped, he mumbles something about a horribly sour taste in his mouth.

____

f. Compound F is mixed with sodium hydroxide (NaOH). After the reaction is completed, the products are analyzed and found to be salt (NaCl) and water.

____

continued

Assignment 2.4 (continued)

4. In combustion reactions, hydrocarbons react with oxygen to produce carbon dioxide and water. Fires are an everyday example of combustion.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

   a. Based on what you know about fires, what is missing from the reactant side of the equation in order to trigger the reaction? What product is not shown in the above reaction, but would be expected to be given off by a fire? Give an example of what you could use to trigger a combustion reaction. *(3 marks)*

   b. Irene and her friends are hiking through the woods and find a nice spot to set up camp for the evening. To warm up, they collect some kindling and small, dry sticks to start a fire in a pit. Once the fire is burning, Irene and her friends begin setting up their tents. When they return from the work, they notice that their fire has died out, with barely any embers remaining. What happened to the combustion reaction? *(3 marks)*

continued

Assignment 2.4 (continued)

c. Joe is hosting a summer cookout and barbecuing for his friends. As he fires up his grill, Joe feels the heat from the flames escaping into the air. He reasons that if he can contain the heat from his barbecue, then his burgers will cook faster, and so covers his grill with an air-tight lid. When he next checks on his meat, Joe notices that the fire has gone out completely. What happened to the reaction? *(3 marks)*

Lesson 13: Acids and Bases at Home, in Industry, and in Our Bodies

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe how acids and bases are used in households, industries, and living systems
- ❑ suggest safe storage tips for acids and bases

Key Words

- hydrochloric acid
- formic acid
- citric acid
- nitric acid
- ammonia
- sulfuric acid

Introduction

Carbonated beverages and vinegar are only two of many instances where acids and bases are used in our daily lives. From explosives to fertilizers, and even our bodies, acids and bases are present everywhere.

Acids and Bases in Biological Systems

Following are some acids and bases found in biological systems.

- **stomach acid (hydrochloric acid) HCl**

  You may have noticed in Module 2, Lesson 12, that stomach fluids have a pH of 1.7—a strong acid. This hydrochloric acid, along with some enzymes, is responsible for partially breaking down proteins in the food you eat.

How does your stomach keep from digesting itself?

Your stomach is a crescent-shaped, hollow organ about the size of a large melon. The average adult stomach holds about three quarts (three litres) of fluid. Your stomach is made up of a variety of layers, including

- the **serosa**—the outer layer that acts as a covering for the other layers
- two muscle layers—the middle layers that propel food from the stomach into the small intestine
- the **mucosa**—the inner layer made up of specialized cells, including **parietal cells**, **g-cells**, and **epithelial cells**

The innermost lining of your stomach secretes hydrochloric acid from specialized parietal cells. This acid is so concentrated that if you were to place a drop on a piece of wood, it would eat right through it. Your stomach also contains epithelial cells that produce bicarbonate, a base, to neutralize the overall acidic environment.

In some individuals, this defence system does not work as well as it should due to a poor blood supply to the stomach, or because of an overproduction of acid. The stomach lining in these people can develop open sores called gastric ulcers.

- **ant stings (formic acid)**

  Many species of ants can spray formic acid to defend themselves and use it as a scent. (Formic acid is named after ants—the latin name for ants is *formica*.)

- **pancreatic fluid (includes sodium bicarbonate)**

  The pancreas contains sodium bicarbonate ($NaHCO_3$). This neutralizes the acidity of the fluid leaving the stomach, raising its pH to about 8. Since the stomach is the only organ that can manage strong acids, this raising of pH in the fluid leaving the stomach is important.

- **citrus fruit (citric acid)**

  Citric acid is an organic acid found in citrus fruits such as oranges (pH 3.5), grapefruit (pH 3.1), and lemons (pH 2.6). Citric acid gives the juice of citrus fruits their characteristic tangy taste.

Examples of Acids and Bases in Industrial Processes

Following are examples of acids and bases found in industrial processes.

- **explosives (nitric acid) HNO_3**

  Nitric acid is very important for certain types of reactions, especially in the fertilizer and explosives industries. The principal use for nitric acid is the production of fertilizers, explosives, flares, and rocket propellants. In making explosives, nitric acids react with toluene in the presence of sulfuric acid to form trinitrotoluene (TNT).

  Other uses include manufacturing nylon, and testing whether certain jewellery is genuine gold or platinum. Nitric acid has a powerful oxidizing agent that, when mixed with hydrochloric acid, dissolves many metals except gold or platinum.

- **fertilizers (ammonia) NH_3**

  Plants need light, water, carbon dioxide, and warmth for growth to take place. Plants also require several elements for growth; these elements include nitrogen, potassium, and phosphorous. To help the soil supply all the nutrient requirements for plant growth, farmers often provide nitrogen compounds in the form of fertilizers. The most commonly lacking element is nitrogen. Nitrogen is provided through the use of a base called ammonia (NH_3).

  Ammonia reacts with nitric acid to form an ammonium salt that contains nitrogen:

  $$HNO_3(aq) + NH_3(g) \longrightarrow NH_4NO_3(aq)$$

  nitric acid + ammonia ⟶ ammonium nitrate

  Ammonium nitrate contains nitrogen that is easily absorbed by the plants.

- **speeding up industrial chemical reactions (sulfuric acid) H_2SO_4**

  Sulfuric acid has a variety of uses in the production of goods and is considered one of the most important industrial chemicals. The United States alone produces more than 40 million tons of sulfuric acid to meet industrial needs.

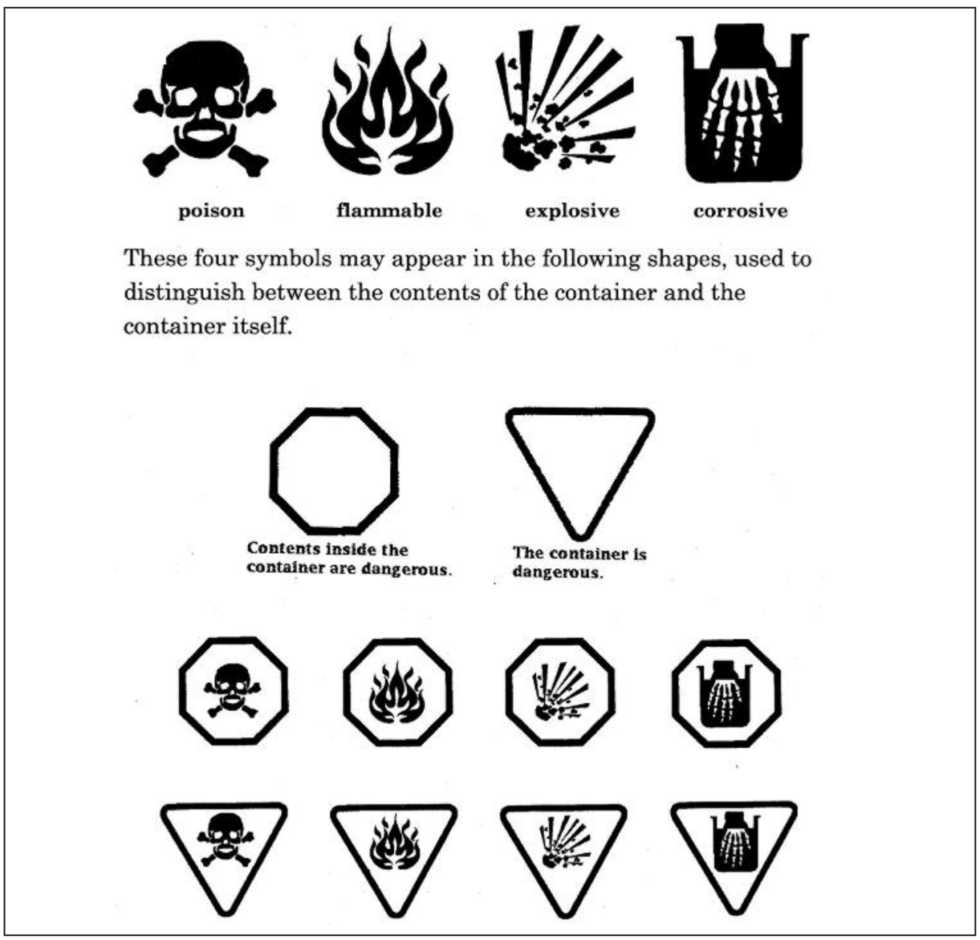
  - The most widespread use of sulfuric acid is in the production of fertilizers.
  - Sulfuric acid is commonly used to make detergents, dyes, pigments, explosives, and drugs.
  - It is used in petroleum refining to wash impurities out of gasoline and other refinery products.
  - Artificial clothing fabrics such as rayon are manufactured using sulfuric acid.

- Sulfuric acid is used to power the batteries of automobiles.

Sulfuric acid is **very toxic**. It may be fatal if inhaled or swallowed, and it is **corrosive** to the eyes, skin, and respiratory tract. It may cause blindness and permanent scarring. It also causes lung injury and these effects may be delayed. Strong inorganic acid mists containing sulfuric acid are **carcinogenic**.

If you are involved in an acid spill, let someone know by calling out. Go immediately to an eyewash station if the spill involves your eyes, or go to a shower if acid has spilled on other parts of your body or on your clothes. You should receive training on lab procedure whenever beginning work in a lab.

The warning symbols shown below represent the Hazardous Household Product Symbols (HHPS). These symbols are familiar to anyone using household products. When using household products, make certain you are aware of the meanings of the symbols.



* Source: Hazard Symbols. Health Canada, 2004. Reproduced with the permission of the Minister of Health, 2012.

The following WHMIS (Workplace Hazardous Materials Information System) chart provides a quick review of the symbols associated with the workplace. You should have enough knowledge of these symbols to understand the hazards associated with acids and bases. Acids and bases would have warning labels dealing with corrosive and reactive hazards.

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

* Source: WHMIS Symbols. Health Canada, 2011. Reproduced with the permission of the Minister of Health, 2012.

Acids and Bases in Your Home

Following are some examples of acids and bases found in homes.

- **window cleaner (ammonium hydroxide) NH_4OH**

  Window cleaners contain a dilute solution of ammonium hydroxide. Ammonium hydroxide is a weak base, but it is able to dissolve protein and oils (such as those in bug bites and fingerprints).

  Window cleaners often contain ammonia that can burn the skin and irritate the eyes and lungs. If ammonia is combined with chlorine bleach, it can form deadly chlorine gas.

  Dispose of cleaners by pouring small amounts into the toilet and flushing. Larger amounts of household cleaners should be taken to a chemical disposal centre.

  Household cleaners should always be kept in a locked place out of the reach of children.

- **Drain cleaner**

  Drain cleaners are also called household lye. They are corrosive bases usually containing sodium hydroxide (NaOH) and/or potassium hydroxide (KOH), and are used to breakdown organic materials. These substances can cause severe burns to the mouth, esophagus, and stomach, even when ingested in very small quantities.

  Many drain cleaners lack any odour or taste, and large amounts can be ingested before any reaction takes place. These properties make it very important to keep drain cleaners out of the reach of children and pets.

- **antacids (aluminum hydroxide) $Al(OH)_3$**

  As discussed earlier, acid is present in the stomach to digest food. Heartburn occurs when small amounts of this acid rise up into the esophagus—the tube that carries food from the mouth to the stomach. This is called **reflux**.

  The gullet, unlike the stomach, does not have a protective lining. So when it is exposed to the acid, it can become inflamed and painful. Most antacids are made of aluminum hydroxide (some are made of a salt—calcium carbonate). An antacid tablet would be taken in order to neutralize the hydrochloric acid coming from the stomach and causing pain in the esophagus.

- **pickles (acetic acid)**

  A pickle's sour taste is due to the acetic acid used to prevent the growth of organisms in the cucumber or other vegetable being pickled. It is important to be careful when pickling vegetables, making certain you follow a recipe carefully, using the proper strength of acid.

- **baking powder and baking soda**

  Both baking powder and baking soda have sodium bicarbonate ($NaHCO_3$) as one of the main ingredients. Baking powder has included in its list of chemicals a compound that produces an acid when dissolved in water. Baking soda must have an acid, such as lemon juice, vinegar, or sour milk, added. The acid reacts with sodium bicarbonate to produce carbon dioxide. As the cake heats in the oven, the carbon dioxide gas expands and a nice, light cake results.

- **soaps and detergents**

  Soaps are common cleaning agents in the home. Soaps are made by boiling fat in sodium hydroxide.

  sodium hydroxide + fat $\longrightarrow$ glycerol + soap

  Glycerol is a by-product that is used in hand lotions.

  You may have heard how soap used to be made. A solution of lye is mixed with water and then allowed to cool (sodium hydroxide heats up when dissolved in water). Animal fat is also heated, the lye is added, the fat and lye are mixed together, and lye soap is formed.

  All soap is made using variations of the method described. Perfumes and softeners are added to make the soaps smell nice and condition skin. Soaps are not as good for washing clothes because they tend to form a scum in hard water.

  Detergents have been developed to overcome the problem of scum with hard water. Originally, phosphates were used in the production of detergents but they were a fertilizer and had disastrous effects on the environment. Modern detergents no longer use phosphates.

Learning Activity 2.16: Applications of Acids and Bases

1. The stomach produces its own hydrochloric acid to aid in the digestion of food and yet it doesn't damage itself. Three types of cells—parietal cells, g-cells, and epithelial cells—help in the process of hydrochloric acid production and stomach protection. Describe how your stomach is protected from the acid it produces.

2. The stomach produces its own hydrochloric acid and has its own mechanism for protection. The small intestine cannot manage such low pH material. How does your body raise the pH of the fluid entering the small intestine?

continued

Learning Activity 2.16 (continued)

3. Name three ways that sulfuric acid is used as an aid in industrial production.
4. Name at least two WHMIS and two HHPS symbols that could be used with sulfuric acid as hazard alerts.
5. Name the common fertilizer chemical used by farmers to provide nitrogen for plants.
6. What common explosive is produced from nitric acid?
7. State whether the following household chemicals contain acids or bases. If you know the name of the acid or base, include it in your answer.
   a. soap
   b. drain cleaner
   c. pickle juice
   d. antacid
   e. baking powder
   f. window cleaner
8. What property of bases makes them good window cleaners?
9. What is heartburn and why is an antacid used to help deal with it?
10. Why can pickles be left for a long time in a refrigerator without spoiling?
11. What is the basic difference and what is the basic similarity between baking powder and baking soda?
12. If you forgot to include baking powder in your cake, what would be the result?

Check the Learning Activity Answer Key found at the end of this module.

Summary

From the cleaning solutions in your home, to the dyes and clothes produced in factories, acids and bases are present everywhere; they are even found within our own bodies. In the next lesson, you will discover what exactly happens when acids and bases react with one another.

LESSON 14: NEUTRALIZATION REACTIONS

Lesson Focus

After completing this lesson, you will be able to

- ❑ define the terms *neutralization* and *salt*
- ❑ write balanced chemical equations for neutralization reactions
- ❑ explain why a salt and water form in a neutralization reaction
- ❑ discuss why a neutralization reaction is classified as a double displacement reaction

Key Words

- neutralization
- salt

Introduction

The table salt we use to flavor and preserve our food is chemically known as sodium chloride (NaCl). While we refer to it as simply "salt," the term *salt* also refers to the group of ionic compounds formed after an acid and a base meet and neutralize each other. Here, we will discuss this neutralizing property of acids and bases more closely, but first we will quickly review the rules for writing chemical equations. You may also wish to refer back to Lesson 9 and refresh yourself on the in-depth rules of balancing equations.

Writing Equations: Steps to Remember

1. Reactants are always located to the left of the reaction arrow. Reactants are the materials that are present before the reaction begins. Products are always located to the right of the reaction arrow. Products are present after the reaction has taken place.

$$\underbrace{4Cu + O_2}_{\text{Reactants}} \longrightarrow \underbrace{2Cu_2O}_{\text{Product}}$$

2. The physical state of the reactants and products is often stated. In this case the copper is a solid, oxygen is a gas, and copper (I) oxide is a gas.

$$\underbrace{Cu_{(s)} + O_{2(g)}}_{\text{Reactants}} \longrightarrow \underbrace{Cu_2O_{(g)}}_{\text{Product}}$$

3. Subscripts are used in the chemical formula of a compound. The subscript 2 in Cu_2O indicates that two atoms of copper combine with one atom of oxygen to form one molecule of copper (I) oxide. **Subscripts cannot be changed when balancing equations.**
4. **Coefficients are used to balance equations.** When an equation requires balancing, whole numbers can be placed in front of any compound to increase the numbers of atoms necessary to illustrate the law of conservation of mass. When you are finished balancing an equation, the number of atoms of each element involved in the reaction must be equal on both sides of the equation.

$$\underbrace{4Cu_{(s)} + O_{2(g)}}_{\text{Reactants}} \longrightarrow \underbrace{2Cu_2O_{(g)}}_{\text{Product}}$$

Learning Activity 2.17: Analyzing Equations

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O$$

1. Name the reactants and products in this reaction.
   a. Reactants
   b. Products
   c. What does the subscript *(aq)* mean?
   d. Name a compound that shows a subscript value.

continued

Learning Activity 2.17 (continued)

e. How many molecules of each compound below are used or produced in the reaction?
   - i. sodium hydroxide
   - ii. water

2. Balance the following chemical equations.
   a. $Ca + S \longrightarrow CaS$
   b. $HCl + NaOH \longrightarrow NaCl + H_2O$
   c. $Na + H_2O \longrightarrow NaOH + H_2$
   d. $CH_4 + O_2 \longrightarrow CO_2 + H_2O$

Check the Learning Activity Answer Key found at the end of this module.

Balancing Neutralization Reactions

When an acid and a base are placed together, they react to form a **salt** and water. This type of reaction is called a **neutralization reaction**. An example of a neutralization reaction is shown below.

$HCl + LiOH \longrightarrow LiCl + H_2O$ (Balanced example equation)

Acid (HCl) Base (LiOH) Salt (LiCl)

1. The acid provides the chloride and the base provides the metal magnesium in the formation of the salt $MgCl_2$ (magnesium chloride). It is characteristic of a neutralization to follow this pattern of salt formation.
2. A salt is formed from the negative ion of the acid and the positive ion of the base in a neutralization reaction.
3. It is also characteristic of a neutralization reaction to use the hydrogen (H) from the acid and the hydroxide (OH) from the base to form water.

Neutralization Reactions Are Double Replacement Reactions

Double replacement reactions were first studied in Lesson 10. A typical double replacement reaction is shown below.

$$\text{Compound} + \text{compound} \longrightarrow \text{compound} + \text{compound}$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

The sample neutralization reaction illustrates the characteristics of a double replacement reaction. The two compounds, hydrochloric acid and sodium hydroxide, react to form two new compounds, sodium chloride (salt) and water. The hydrogen in hydrochloric acid combines with the hydroxide in sodium hydroxide to form water. The sodium in sodium hydroxide combines with the chloride in hydrochloric acid.

Learning Activity 2.18: Neutralization

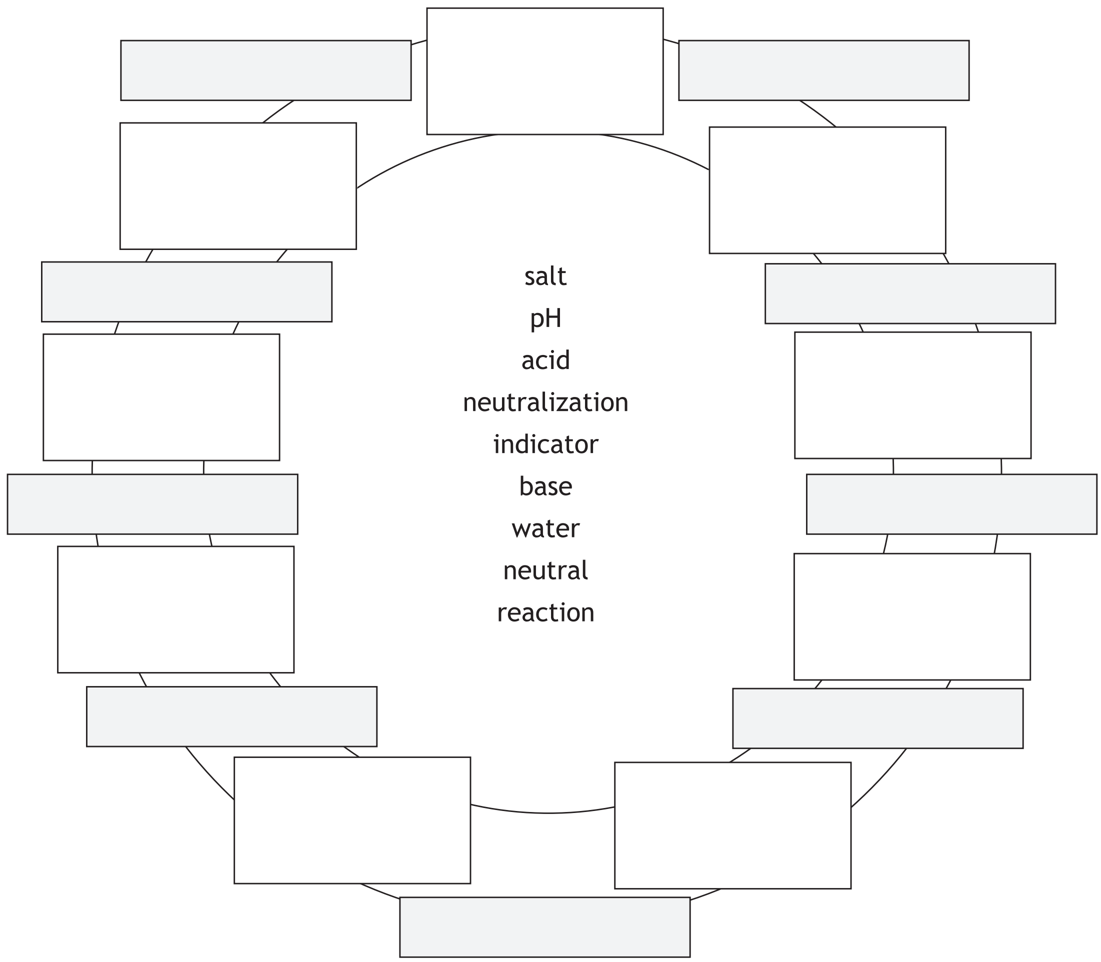
Balance the neutralization reactions shown below. Name each of the compounds (except water) in each equation.

1. $HBr + KOH \longrightarrow KBr + H_2O$
2. $HI + NaOH \longrightarrow NaI + H_2O$

continued

Learning Activity 2.18 (continued)

3. Read the list of words in the circle. Select one word and place it in any unshaded rectangle. In the next unshaded rectangle, place another word that is related to the first. Plan ahead; the last few words will be tricky to place. You may wish to add some linking comments in the shaded rectangle between words to make the ideas flow better.



4. A double replacement reaction in general form is shown below.

   $$AB + CD \longrightarrow AD + CB$$

   Use the neutralization reaction between hydrochloric acid and sodium hydroxide to illustrate how a neutralization reaction is a double displacement reaction.

continued

Learning Activity 2.18 (continued)

5. Why are a salt and water always formed in a neutralization reaction?

Check the Learning Activity Answer Key found at the end of this module.

Summary

When an acid and base are placed together, they perform a double replacement reaction to form water and a salt, which is an ionic compound. The acid provides the negatively charged ion for the salt, while the base provides the positively charged ion.

Assignment 2.5: Acids and Bases (16 marks)

1. A laboratory has discovered that an unknown solution, named Compound X, has proven effective in breaking down plastics into recyclable products. An investigation is made to fully analyze and classify Compound X.

   a. After experimenting with Compound X, the laboratory noted several unique properties, listed below. Is Compound X an acid (formula HX) or a base (formula XOH)? *(1 mark)*

   Properties of Compound X:

   — conducts an electric current

   — reacts violently with alkali metals

   — releases a gas when put into solution with bicarbonate

   b. During an experiment, a beaker of Compound X was spilled on the laboratory floor, causing fumes to rise into the air. What should be added to the spill in order to neutralize Compound X—hydrochloric acid (HCl) or sodium hydroxide (NaOH)? Write a balanced neutralization reaction using the appropriate solution and the general formula. *(2 marks)*

2. Complete the following neutralization reactions.
   (1 mark x 7 = 7 marks)

   a. ______ + $Ca(OH)_2 \rightarrow CaCl_2 + H_2O$

   b. HI + ______ $\rightarrow$ LiI + H_2O

   c. HBr + KOH $\rightarrow$ ______ + H_2O

   d. ______ + ______ $\rightarrow$ NaF + H_2O

   e. $Mg(OH)_2$ + ______ $\rightarrow$ MgS + H_2O

   f. ______ + NaOH $\rightarrow Na_2CO_3 + H_2O$

continued

Assignment 2.5 (continued)

3. How do acids and bases operate in your digestive system when you eat a cheeseburger? *(4 marks)*

4. Ammonium nitrate (NH_4NO_3) is a compound used in the manufacturing of explosives. Name at least two WHMIS or HHPS symbols that you would expect to find when working with this compound. (*2 marks*)

Lesson Focus

After completing this lesson, you will be able to

- ❑ write balanced chemical equations for the formation of acid rain
- ❑ distinguish acid rain from normal rain in terms of pH
- ❑ identify sources of sulfur oxide and nitrogen oxide emissions
- ❑ describe the effect of acid rain on lakes
- ❑ describe the formation of smog
- ❑ differentiate between ground-level ozone and upper-level ozone
- ❑ discuss the impact of CFCs on upper-level ozone
- ❑ identify sources of airborne particulates
- ❑ write balanced chemical equations for the combustion of fossil fuels such as methane (CH_4), gasoline (C_8H_{18}), and alcohols such as ethanol (CH_3CH_2OH)

Key Words

- acid precipitation
- pollutants
- London-type smog
- Los Angeles–type smog
- sulfur oxides
- nitrogen oxides
- ozone
- CFCs

Introduction

Our health is affected by many natural and human-caused environmental factors. In Grade 7, you studied potential harmful effects of some substances in the environment. In Grade 8, you studied the hydrological cycle and water pollution. You will have heard about the terms acid rain, smog, and ozone. In this lesson, you will continue studying some environmental issues linked with air pollution.

Natural Acid Precipitation

We will use the term **acid precipitation**, since not just rain but sleet and snow can be responsible for forming acid solutions that fall on the ground and lakes.

Acid precipitation has always existed. Moisture falling to Earth **combines** with carbon dioxide **in the atmosphere** to form carbonic acid, **a weak acid**. As a result, even though water is neutral (pH 7), rainwater, under normal conditions, will have a pH of approximately 5.3. This natural pH level of precipitation forms a weak acid that is considered normal.

$$CO_{2(g)} + H_2O_{(l)} \longrightarrow \underset{\text{carbonic acid}}{H_2CO_{3(aq)}}$$

In the natural world, the carbon dioxide formed by forest fires, volcanic activity, and animal respiration is equal to the carbon dioxide used up in the formation of carbonic acid and in photosynthesis. Carbonic acid is a weak acid, not harmful to the environment in its natural concentration.

Human-Caused Acid Precipitation

Human-caused acid precipitation has a considerably lower pH, ranging between 5 and 3. This increased acid strength is a result of the formation of sulfuric (H_2SO_4) and nitric (HNO_3) acids. How do these stronger, more destructive forms of acid get into our atmosphere?

Sulfuric and nitric acids are created when precipitation falls through an atmospheric blanket of oxides of nitrogen (NO and NO_2) and sulfur (SO_2). Water combines with the oxides to form sulfuric and nitric acids.

We need to realize that nitrogen and sulfur oxides have always been present in the atmosphere, but their concentrations due to natural causes such as volcanoes and lightning have been very low.

Modern industrial processes make use of fossil fuels for the production of energy and as part of the refining of oil. Consequently, the levels of these oxides have risen dramatically in the last century. We now look at oxides of sulfur and nitrogen as **pollutants**. A pollutant is a substance that is present in large enough quantities to have an adverse effect on animal and plant life.

Sulfur Oxides

The burning of coal in power plants is a major source of **sulfur oxides**. Sulfur oxides combine with water in the atmosphere to produce forms of sulfuric acid.

$$\underset{\text{sulfur dioxide}}{SO_2} + H_2O \longrightarrow \underset{\text{sulfurous acid}}{H_2SO_3}$$

$$\underset{\text{sulfur trioxide}}{SO_3} + H_2O \longrightarrow \underset{\text{sulfuric acid}}{H_2SO_4}$$

Nitrogen Oxides

Internal combustion engines—both diesel and gasoline—are responsible for the production of **nitrogen oxides**. Nitrogen oxides combine with water vapour to produce forms of nitric acid:

$$\underset{\text{nitrogen dioxide}}{2NO_2} + H_2O \longrightarrow \underset{\text{nitrous acid}}{HNO_2} + \underset{\text{nitric acid}}{HNO_3}$$

$$\underset{\text{nitric oxide}}{4NO} + 3O_2 + 2H_2O \longrightarrow \underset{\text{nitric acid}}{4HNO_3}$$

Fossil Fuels

Some common fuels for combustion engines include methane, gasoline, and ethanol.

Methane combustion:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Gasoline combustion:

$$2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$$

Ethanol combustion:

$$CH_3CH_2OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

Recall from Lesson 10 that combustion reactions require hydrocarbons and oxygen, but not nitrogen. How then, do combustion engines produce nitric acids? Remember that the air around us is a combination of many gases. When a combustion engine takes in oxygen from the atmosphere, there is nitrogen present in the air that also enters. The nitrogen combines with oxygen under the high internal temperature to form nitrogen oxides. So although this is an unintended chemical reaction, driving a car also contributes to human-caused acid precipitation.

Effects of Acid Rain

Between 1990 and 2005, Canada decreased its sulfur dioxide emissions by more than half, and reductions are also underway in the United States. Despite this progress, however, the recovery of natural ecosystems has been much slower than anticipated. Acid rain continues to affect our lakes, forests, wildlife, and even our health.

Lakes

The more acidic a lake becomes, the fewer species it can support. Plankton and invertebrates are among the first to die from acidification, and when the pH of a lake drops below 5, more than 75 percent of its fish species disappear. This causes a ripple effect in the food chain, and has a significant impact on fish-eating birds, such as loons.

Not all lakes exposed to acid rain become acidified. Bases found in certain types of rock and soil help to neutralize acidity. Unfortunately, most acid rain falls in eastern Canada, where coarsely textured soil and granite bedrock have little ability to neutralize acid. Models predict that, even after 2010 emissions targets are reached, up to one-quarter of the lakes in eastern Canada will remain chemically damaged.

Forests

Acid rain dissolves nutrients and helpful minerals in the soil and washes them away before trees can use them to grow. It also releases toxic chemicals, such as aluminum, which interfere with the uptake of nutrients. Nutrient-starved trees can experience stunted growth and loss of leaves, and are more vulnerable to climatic stresses, pests, and disease.

Like lakes, a forest’s ability to withstand acid rain depends on the neutralizing capacity of its soil. Forests in eastern Canada receive roughly twice the level of acid they can tolerate without long-term damage. Forests in coastal and upland areas also experience damage from acidic fog.

Human Health

The sulfur dioxide that contributes to acid rain can also react with other chemicals in the air to form tiny sulfate particles that can lodge deep within the lungs and cause respiratory problems for humans.

Corrosion

Acid rain can also accelerate the corrosion of materials such as limestone, sandstone, marble, brick, concrete, and metal, causing serious concerns for older buildings and outdoor sculptures and monuments. Acid rain damages stonework because it dissolves calcium carbonate, leaving behind crystals in the rock when it evaporates. As the crystals grow, they break apart the stone.

Acid Rain and Other Pollutants

The interactions between acid rain, ultraviolet (UV) radiation, climate change, and other human-related stresses can magnify their impacts. For example, because acidity reduces the amount of dissolved organic matter in lake water, acidic lakes are clearer and therefore more vulnerable to the effects of increased UV levels.

Climate change also affects acid levels in lakes, because hot, dry conditions convert harmless sulfur compounds that have accumulated in wetlands into acid-forming sulfates. When it rains, these sulfates are flushed into surrounding lakes, boosting their acid levels.

As acid rain continues to fall, there is an impact on all wildlife, as we would expect with any interruption in the food chain. Canada has a reputation for natural habitats and our tourist industry builds on this expectation. As fish, animals, and plants disappear, our tourist industry is affected.

According to Environment Canada, acid rain is worst in Atlantic Canada. This is because many of the water and soil systems in this region lack natural alkalinity—such as a lime base—and therefore cannot neutralize acid naturally. Provinces that are part of the Canadian Precambrian Shield (including northern Ontario, Quebec, and northern New Brunswick) are hardest hit because their water and soil systems cannot fight the damaging consequences of acid rain. In fact, more than half of Canada consists of susceptible hard rock (e.g., granite) areas that cannot neutralize the effects of acid rain. If the water and soil systems were more alkaline—as in western Canada—they could neutralize or buffer against acid rain naturally.

In western Canada, lower levels of industrialization—relative to eastern Canada—combined with natural factors such as eastwardly moving weather patterns and resistant soils (i.e., soils better able to neutralize acidity) have preserved much of the region from the ravages of acid rain. However, not all areas in western Canada are naturally protected. Lakes and soils resting on granite bedrock, for instance, cannot neutralize precipitation. These are the conditions found in areas of the Canadian Shield in north-eastern Alberta, northern Saskatchewan, and Manitoba, and parts of western British Columbia. Lakes in these areas are as defenceless to acid rain as those in northern Ontario. They must be shielded from exposure to acid rain; if not, environmental damage could be serious over time.

While the majority of western Canada does have a natural buffer, we cannot be complacent. By carefully monitoring the environment and applying strict pollution control when necessary, we should be able to prevent acid rain from becoming an environmental concern in western Canada.

Smog

We have all heard of smog. The name comes from a combination of the words *smoke* and *fog*.

There are two types of smog:

1. **London-Type Smog (Sulfur Dioxide Smog)**

   This type of smog is called London-type smog due to the conditions that can exist in this city. In December 1952, fog built up over London. It was cold; Londoners burned their coal stoves even more than usual. The thick fog kept the smoke at ground level. The combination of smoke and fog (smog) remained for five days. More than 4000 people died from smog-related causes.

   The culprit in London-type smog is the formation of sulfur oxides by burning fossil fuels—coal, in the London case. The sulfur oxides react with oxygen and water vapour to form sulfuric acid in the atmosphere. Londoners breathed a mist of sulfuric acid vapour that irritated the lungs, causing oxygen starvation and, in extreme cases, heart failure.

2. **Los Angeles–Type Smog (Photochemical)**

   This type of smog is free from sulfur dioxides but is dependent on nitrogen oxides for the process to begin. Automobiles are responsible for this type of smog. Nitrogen in the air and the heat of combustion in the car engine result in the formation of nitrogen dioxide (NO_2). Ultraviolet light acts on the nitrogen dioxide to form ground-level ozone (O_3).

   Los Angeles often has ideal conditions for photochemical fog; it is called photochemical since sunlight is required to provide the energy needed to push forward the chemical formation of ozone. LA's huge number of automobiles and abundant supply of sunlight are ideal for promoting photochemical smog.

   Ozone can cause lung damage over a period of time, particularly in children. Ozone, because it is an unstable molecule, will also combine with hydrocarbon molecules to form pollutant hydrocarbons that accompany smog, causing discomforts such as stinging eyes and obnoxious smell.

   There are health concerns associated with children at play and people who exercise during smog. A 1984 study conducted at the University of Southern California showed that children raised in the South Coast Air Basin suffer a 10 to 15 percent decrease in lung function, compared to children who grow up where the air is less polluted. Most cities have a smog alert to warn parents and exercisers of the potential hazards to health from playing or exercising outside.

Upper-Level Ozone

We consider upper-level ozone to be "good" ozone. The upper-level ozone layer is a layer of ozone gas that surrounds Earth 15 to 35 kilometres above its surface. At this level in the atmosphere, ozone is able to filter out high-energy, short wavelength radiation from the Sun, protecting us from its harmful effects. Upper-level ozone is far enough from us that we do not breathe it, leaving us free from its harmful effects.

Just after World War II, scientists involved in refrigeration discovered a group of chemicals that seemed to be just what they were looking for. These chemicals were easy to make, fireproof, and non-poisonous. Not only were these chemicals good at keeping things cold, but they were useful in making insulation products, packaging, and many other products.

This group of chemicals has the long, technical name of chlorofluorocarbons, which has been shortened to **CFCs**.

Halons are another group of chemicals that are just as important. They are used mainly for fire protection.

Everything seemed fine for many years. Factories around the world produced refrigerators, air-conditioning units, and all types of insulation. But in the mid-1980s, scientists discovered a "hole" in the ozone layer over the Antarctic.

When the "hole" was first discovered in the ozone layer over the Antarctic, scientists from around the world met to discuss this development. Their belief was that while CFCs and halons do not cause environmental damage in the air near the ground, they travel very slowly upward until they reach the ozone layer and then begin to eat away at the ozone.

Scientists can't tell us yet exactly how much damage has already been done, nor how quickly more damage will occur. But we do know that these chemicals can stay up there in the ozone layer for up to 100 years and may be destroying ozone for that period of time.

By sending weather balloons up into the ozone layer, and from information gathered by space satellites, scientists have seen some large gaps or holes in the ozone layer at certain times of the year. To date, these gaps have been observed over both the North and South Poles.

Airborne Particles

Airborne particulates are considered a pollutant if they exist at a size of less than 10 micrometres. A **micrometre** is one millionth of a metre. The dot on an *i* on this page would have a diameter of approximately 400 micrometres.

Particles larger than 10 micrometres generally get caught in the nose and throat, never entering the lungs. Particles smaller than 2.5 micrometres in diameter can get down into the deepest portions of your lungs where gas exchange occurs between the air and your bloodstream, oxygen moving in and carbon dioxide moving out. These are the really dangerous particles because the deepest (alveolar) portions of the lung have no efficient mechanisms for removing them. If these particles are soluble in water, they pass directly into the bloodstream within minutes. If they are not soluble in water, they are retained in the deep lung for long periods (months or years). The small particles might be responsible for the clotting of blood. They can also cause and increase breathing and respiratory problems, irritation, inflammation and damage to the lungs, and premature death.

Fossil fuel combustion in motor vehicles, power plants, and large industries, as well as industrial processes and solvent use, are major sources of these other pollutants. Smoking is the single most dangerous source of particulate pollution because it results in the direct inhalation of airborne particles.

Particulate matter is also associated with reduced visibility and with poor air quality. The presence of particles in the air reduces the distance at which we can see the colour, clarity, and contrast of faraway objects because the particles in the atmosphere scatter and absorb light.

The most obvious effect of particulate deposition on vegetation is the physical smothering of the leaf surface. This will reduce light transmission to the plant, in turn causing a decrease in photosynthesis. Particle composition may cause both direct chemical effects on the plant and indirect effects through impacts on the soil environment. Particle accumulation on the leaf surface may increase the plant's susceptibility to disease.

Learning Activity 2.19: Air Pollution

1. Nickel smelter operations in Sudbury, Ontario, release sulfur as sulfur dioxide gas in the refining process, as shown in the equation below.

   $$NiS + O_2 \longrightarrow Ni + SO_2$$

   a. What is the metal being refined, according to the equation?

   b. What pollutant is formed in the reaction?

   c. What acid do you think may be formed from the refining process after the SO_2 goes up the smokestack into the atmosphere?

2. If you have access to the Internet, access the Manitoba Government's environmental conservation website: www.gov.mb.ca/conservation/environmental.html. Click on the "Information Brochure and Reports" link under Air Quality. From there, select the report on "Flin Flon and Sulfur Dioxide: Effects on People and the Environment." Based on the information in this report, answer the following questions:

   a. What type of pollutant is being monitored in Flin Flon?

   b. Briefly describe the health hazards from this pollutant.

   c. Briefly describe the environmental hazards from this pollutant.

   d. What is the source of pollution in Flin Flon?

   e. When is a level 1 public warning initiated in Flin Flon?

   f. What is recommended that you do if you feel discomfort?

continued

g. How is the pollution problem being dealt with in Flin Flon?

3. a. What two oxides are responsible for acid rain?

   b. What forms of precipitation, other than rain, are there?

   c. Why is acid rain more of a problem in eastern Canada than in western Canada?

4. a. What is smog?

   b. Why is smog a health concern?

   c. Describe the two kinds of smog and their origins.

5. a. From where does ground-level ozone come?

   b. What harmful effects result from ground-level ozone?

   c. What is the chemical formula for ozone?

   d. What is an important physical property of ozone?

   e. Where is the ozone layer located?

   f. What is the leading cause of ozone depletion?

Check the Learning Activity Answer Key found at the end of this module.

Summary

Global issues such as acid rain, ozone depletion and air pollution are all phenomena that can be explained through chemical interactions at an atomic level. When these reactions are carried out by billions upon billions of molecules, they become the far-reaching pollution problems that plague our world. Here in Manitoba, we need to be aware of the pollution concerns affecting our province, and what we can do as individuals to improve our environment.

Lesson 16: Technology to Reduce Air Pollution

Lesson Focus

After completing this lesson, you will be able to

- ❑ suggest ways you can change your transportation habits to reduce automobile emissions
- ❑ discuss technologies that are being used to reduce sulfur and nitrogen oxide emissions

Key Words

- Montreal Protocol
- clean coal technologies
- catalytic converters
- gasohol

Introduction

It might seem that we produce nothing but pollution, but government and industry are attempting to deal with polluting practices. This lesson looks at a few of the common techniques used to deal with chemicals in the environment.

The Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer is an international agreement that regulates the production and consumption of ozone-depleting substances. Since its inception in 1989, the Montreal Protocol has been ratified by 196 countries and has been amended four times.

The Montreal Protocol is a significant step to solving the depletion of the ozone layer for several reasons:

1. Since it is an international agreement, the environmental benefits will take place over the whole Earth. This type of global agreement is needed to effect the kind of change necessary for saving the stratospheric ozone layer.
2. The Montreal Protocol calls for all use of chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform to be phased out.
3. There is still time for the ozone layer to be restored.

Can I Have an Impact?

Yes, you can! Sulfur dioxide emissions can be significantly reduced through your participation in a few simple actions. Here are some ways you can have an impact:

- Walk, ride your bike, or take a bus to work.
- Share a ride with a friend or coworker.
- Have your engine tuned at least once every six months.
- Check your car tire pressure regularly.
- Use alternative fuels, such as ethanol, propane, or natural gas.
- Avoid unnecessary idling.
- In the winter, warm your car's engine with a block heater for two to three hours prior to driving, rather than plugging in overnight.
- Reduce the number of trips you make in your car.
- Drive at moderate speeds.
- Take the train or bus on long trips.
- Go CFC-free.

Controlling Emissions in Industry

The most effective way to reduce acid rain is to control sources of oxide emissions. Both government and industry in Canada are taking steps to curb emissions.

- The oil industry is developing methods for removing sulfur from crude oil.
- Coal-powered electrical stations are now able to remove sulfur from combustion chambers and smokestacks, reducing sulfur oxide production.
- The federal and provincial governments of Canada have signed the Canada-wide **Acid Rain Strategy for Post-2000**. This agreement is dedicated to government actions in the reduction of acid rain.
- On its website, Environment Canada explains the government's specific plans to reduce acid rain: www.ec.gc.ca/Air/default.asp?lang=En&n=F5CBD0BB-1.

Today, there is generally a greater determination to deal with acid rain than there has been in the past. While the level of acid rain has decreased significantly, the environment requires time and care to return to a healthy condition. In this next section you will learn about some specific technologies used to reduce oxide emissions.

Clean Coal Technologies

The disadvantages presented by coal technologies are serious threats to the environment. However, they are not being ignored by the coal industry. Clean coal technologies that can help reduce harmful emissions fall into four basic categories: pre-combustion, combustion, post-combustion, and conversion categories.

Pre-combustion technologies are incorporated before the coal is burned. They include using chemical and biological methods to remove high percentages of sulfur and ash, or improved coal-washing techniques. During coal cleaning, the coal is crushed and screened for impurities.

Clean coal combustion technologies remove pollutants such as sulfur within the boiler while the coal burns. Calcium-containing materials are added to the burning coals, reacting with the unwanted sulfur emissions to form calcium sulfate. Calcium sulfate can easily be removed and reused in other industries.

Post-combustion technologies focus on cleaning flue gases emitted from the burning of coal before they reach the environment. This sort of cleansing is generally located near the smokestack, and, in particular, in desulfurizing systems called scrubbers. Scrubbers can remove up to 90 percent of sulfur dioxide emissions. They work by spraying the flue gas with an alkaline-containing substance, usually lime or limestone, and allowing the sulfur dioxide to chemically react with it.

Conversion categories of clean coal technology focus on coal changing states. Coal gasification involves heating coal to a minimum of 800 degrees Celsius, while adding oxygen and water. Once coal is in its gaseous state, undesirable components of coal (for example, sulfur and ash) can be removed. The result is a fuel that is easy to transport and exceptionally clean.

Catalytic Converters

The catalytic converter is part of the automobile exhaust system. It converts harmful compounds in exhaust into harmless compounds.

The function of the catalytic converter is to oxidize carbon monoxide (CO) and unburned fuel to carbon dioxide (CO_2) and water, and to reduce the nitrogen oxides to nitrogen gas (N_2).

In a typical passenger car, the catalytic converter, which resembles a muffler in shape, is between the engine and the muffler. It's on the underside of the car, usually underneath the passenger seat.

The inside of the catalytic converter is a honeycomb set of passageways or small ceramic beads coated with catalysts. A chemical reaction takes place to make the pollutants less harmful. There are many passages for the exhaust gases to flow, to allow for the maximum amount of surface area for the hot gases to pass.

After the engine exhaust gases pass through the catalytic converter, the gases go through the muffler. The catalytic converter generally lasts the life of the automobile and rarely has a problem with being clogged or plugged during its lifetime.

Catalytic converters have been standard on North American automobiles since the mid-1970s, and have been responsible for greatly reducing nitrogen oxide emissions and carbon monoxide in vehicles.

Gasohol (10 percent ethanol blend)

Ethanol-blended gasoline, or **gasohol**, is a mixture of gasoline and ethanol. In Manitoba, gasohol contains 10 percent ethanol and 90 percent gasoline.

Gasohol can be used in vehicle engines that use gasoline. Since 1988, all vehicles sold in Canada have been warranted to use gasohol.

Gasohol is considered to have positive environmental effects. Studies show that using gasohol, instead of regular gasoline, reduces carbon monoxide (CO) emissions by as much as 17 percent, carbon dioxide (CO_2) emissions by 4.2 percent, and hydrocarbon emissions by 5 percent. Furthermore, using gasohol also reduces emissions of benzene, which is known to cause cancer.

The downside of gasohol use comes from its vapour, which can be harmful to the ozone layer, particularly in warm weather.

Learning Activity 2.20: Technology Recap

1. State the three basic categories in which clean coal technologies take place, and briefly explain how they work.
2. How does a catalytic converter in a car reduce pollution?
3. Why do you think our government is promoting the use of gasohol?

Check the Learning Activity Answer Key found at the end of this module.

Summary

Recent years have seen promising new technologies applied to control the spread of polluting sulfur oxide and nitrogen oxide emissions. The responsibility for change, however, is not solely in the hands of governments and industries. As a Canadian citizen, we must all examine our lifestyles and consider how we can reduce polluting practices in our day-to-day lives.

Notes

Assignment 2.6: Chemistry in Technology and the Environment (24 marks)

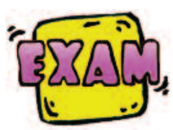
1. Greenlake is a small community in northern Manitoba built around Evergreen Lake. The population is made up mostly of fisherfolk, although there is also a strong tourist industry in the area. Recently, a rare metal has been discovered around Evergreen Lake, and a mining company has built a facility on-site to extract and process the metal. Since the facility opened, its smokestacks have been exhaling emissions into the air, including sulfur dioxides. How might this mining facility affect the ecosystem, animals, and human activities at Evergreen Lake? *(5 marks)*

2. Give five examples of how you can make changes in your daily life to reduce greenhouse gas emissions. *(5 marks)*

continued

3. Because of increased demands for electricity in the northern United States, Manitoba is considering entering a partnership with North Dakota, where a new coal-burning plant will be built in southern Manitoba to provide power for both regions. To keep this plant as environmentally friendly as possible, describe four clean coal technologies that could be installed to reduce harmful emissions. *(4 x 2 marks = 8 marks)*

4. An automobile manufacturer has placed you in charge of designing their newest model. What technologies could you add to the design in order to reduce harmful emissions? Describe how these technologies work, and what specific emissions they control/reduce. *(6 marks)*



This completes your work in the chemistry section of Grade 10 Science. If you have not yet made arrangements to write the **midterm examination**, then do so now. The instructions are provided in the course Introduction.

Completing Your Practice Midterm Examination

Getting the Most Out of Your Practice Midterm Examination

Like the midterm examination that you will be writing, your Practice Midterm Examination is based on Modules 1 to 2. It is very similar to the actual Midterm Examination. This means that if you do well on your practice examination, you should do well on the midterm examination because you will have learned the content. You will also feel more confident and less nervous about writing the examination.

The Practice Midterm Examination and answer key can be found in the learning management system (LMS). Complete the Practice Midterm Examination and then check your answers against the key.

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 Midterm Examination and its answer key.

To get the most out of your Practice Midterm Examination, follow these steps:

1. Study for the Practice Midterm Examination as if it were an actual examination.
2. Review those learning activities and assignments from Modules 1 to 2 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 2, including all of your notes, learning activities, and assignments.
5. Bring the following to the Practice Midterm Examination: pens and pencils (two or three of each), blank paper, and a metric ruler. You may also bring a calculator, although it is not strictly required.
6. Write your Practice Midterm 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.

Submitting Your Assignments

It is now time for you to submit Assignments 2.1 to 2.6 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.

- ❑ Assignment 2.1: Atoms and Ionic Compounds
- ❑ Assignment 2.2: Atomic Bonding
- ❑ Assignment 2.3: Conservation of Mass
- ❑ Assignment 2.4: Chemical Reactions
- ❑ Assignment 2.5: Acids and Bases
- ❑ Assignment 2.6: Chemistry in Technology and the Environment

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

Module 2

Learning Activity Answer Key

Module 2
Learning Activity Answer Key

Lesson 1

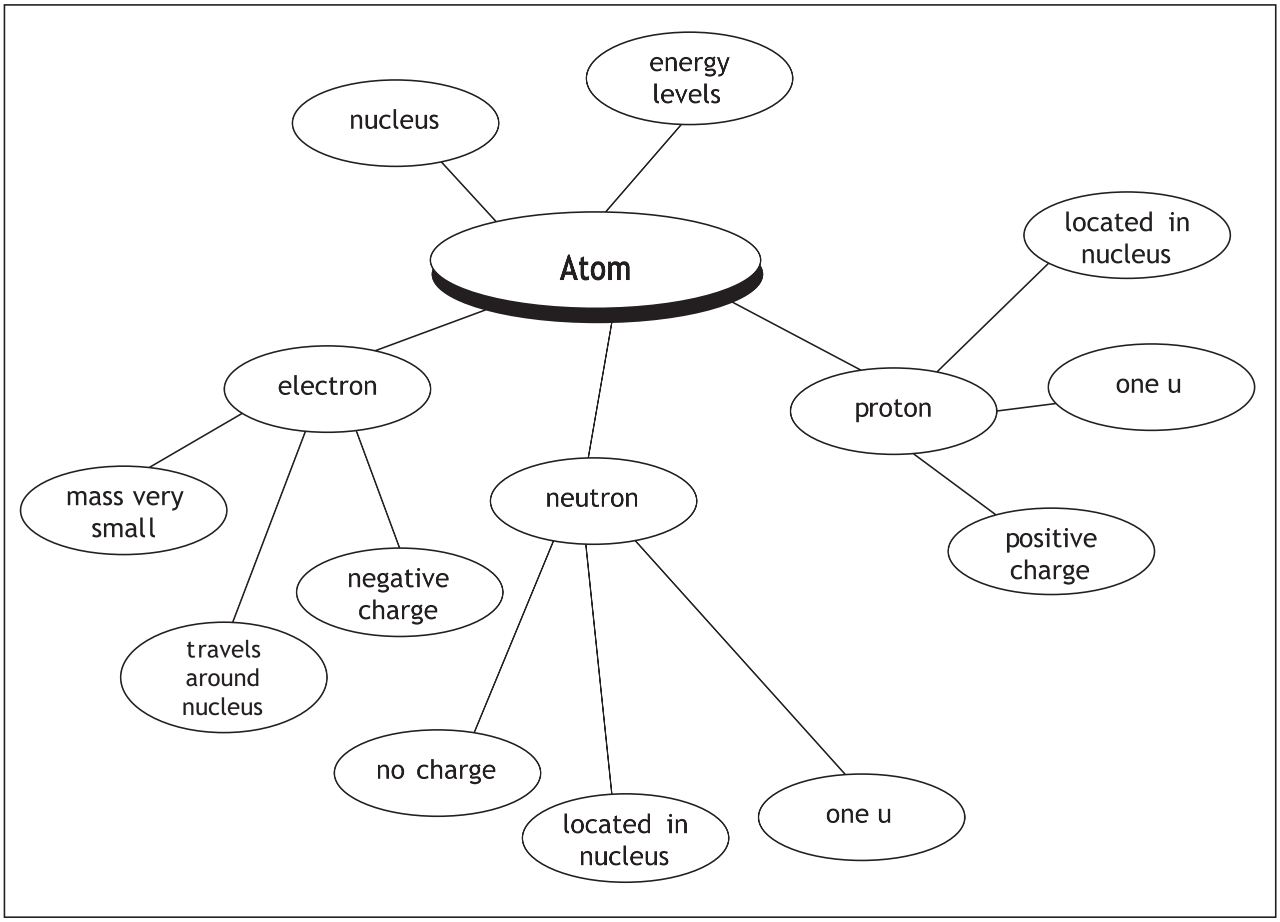
Learning Activity 2.1: Subatomic Particles

	Charge	Location	Mass
Protons	+1	in nucleus	1 u
Electrons	–1	around nucleus	0
Neutrons	0	in nucleus	1 u

Learning Activity 2.2: Subatomic Particles Review

1. An atom of gold has an atomic number of 79 and an atomic mass of 197 u.
   a. How many protons are in one atom of gold? **79**
   b. How many electrons are in one atom of gold? **79**
   c. How many neutrons are in one atom of gold? **118**
   d. How many protons are in 10 atoms of gold? **790**
   e. What is the atomic mass of gold? **197 u**
   f. What is the mass number of gold? **197**
2. What is the unit of atomic mass called and what is its symbol?
   The unit of mass is called an atomic mass unit and its symbol is u.
3. An atom of uranium has an atomic number of 92 and an atomic mass of 238 u.
   a. How many protons are in one atom of uranium? **92**
   b. How many electrons are in one atom of uranium? **92**
   c. How many neutrons are in one atom of uranium? **146**
   d. How many protons are in 10 atoms of uranium? **920**
   e. What is the atomic mass of gold? **238 u**
   f. What is the mass number of gold? **238**

4. Concept maps show connections between ideas. The start of a concept map is shown below. Complete the concept map, using the terms below.



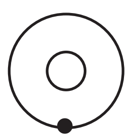
one u	no charge	negative charge
positive charge	travels around nucleus	one u
mass very small	located in nucleus	located in nucleus

LESSON 2

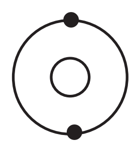
Learning Activity 2.3: Atomic Orbitals

1. Neon follows fluorine and has 10 electrons in its orbits.
   a. How many electrons will neon have in its first orbit?
      Neon has two electrons in its first energy level.
   b. How many electrons will neon have in its second orbit?
      Neon has eight electrons in its next (second) energy level.
   c. The next element, sodium, has one more electron in its orbit. Where will that electron be located?
      Sodium has a single electron in its third energy level.

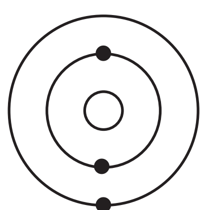
2. Draw Bohr atoms for the first 18 elements. When drawing Bohr atoms, you may draw filled orbits as partial lines with the number of electrons in that orbit written through the line. An example of this appears below.



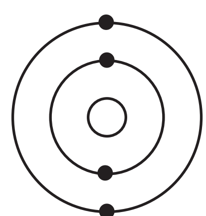
hydrogen



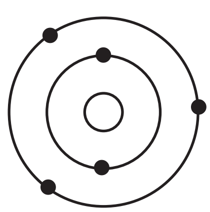
helium



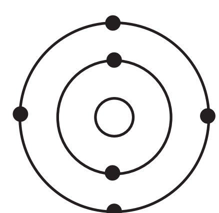
lithium



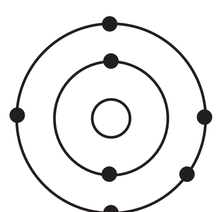
beryllium



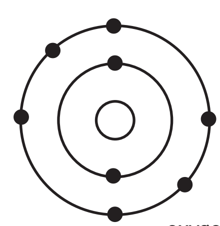
boron



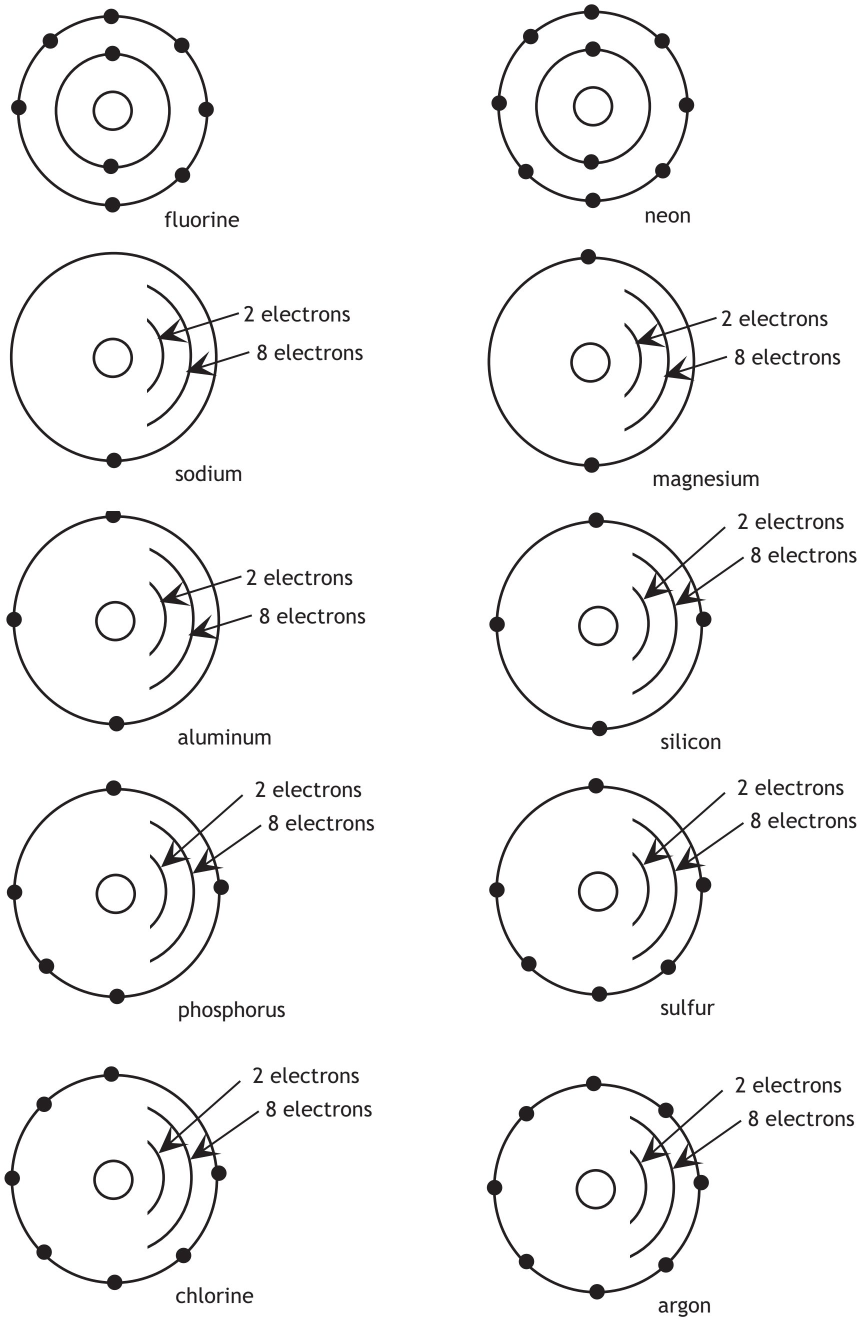
carbon



nitrogen



oxygen


fluorine
neon
2 electrons
8 electrons
sodium
2 electrons
8 electrons
magnesium
2 electrons
8 electrons
aluminum
2 electrons
8 electrons
silicon
2 electrons
8 electrons
phosphorus
2 electrons
8 electrons
sulfur
2 electrons
8 electrons
chlorine
2 electrons
8 electrons
argon

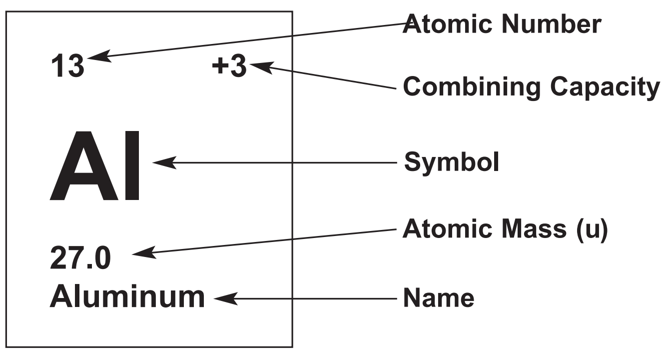
3. Use the atoms you have drawn and arrange the names of the atoms in the table below according to the number of valence electrons in the outer energy level.

	1 Electron in e. level	2 Electrons in e. level	3 Electrons in e. level	4 Electrons in e. level	5 Electrons in e. level	6 Electrons in e. level	7 Electrons in e. level	8 Electrons in e. level
1st energy level	**hydrogen**	**helium**						
2nd energy level	**lithium**	**beryllium**	**boron**	**carbon**	**nitrogen**	**oxygen**	**fluorine**	**neon**
3rd energy level	**sodium**	**magnesium**	**aluminum**	**silicon**	**phosphorus**	**sulfur**	**chlorine**	**argon**

LESSON 3

Learning Activity 2.4: The Periodic Table

1. Complete the information for aluminum in the form below. Use a periodic table to find the information.



2. Look at the periodic table and your notes and note the number of valence electrons in each family. State the number of valence electrons for the families in the table shown below.

Family	Number of Valence Electrons
alkali metals	**1**
alkaline-earth metals	**2**
chalcogens	**6**
halogens	**7**
noble gases	**0**

3. 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.
4. What would happen if fluorine
   a. gained an electron?
      If fluorine gained an electron, it would have the same electron arrangement as neon. It would also become negatively charged.
   b. lost an electron?
      If fluorine lost an electron, it would have the same electron arrangement as oxygen. It would also become positively charged.
5. Make a hypothesis about the effect of lithium's losing an electron. Pay careful attention to the number of protons and electrons in this case.
   If lithium lost an electron, it would have two fewer negative charges than positive charges. Lithium would be more positively charged.
6. A new element has been discovered and all you know is that it is a halogen.
   a. Predict the number of electrons in its outer orbit.
      The new element will have seven electrons in its outer orbit.
   b. Predict its possible atomic number(s).
      The possible atomic numbers are 9, 17, 35.
   c. On what do you base your predictions?
      These predictions are based on the periodic nature of elements. The element would show characteristics of the halogen family.
7. A new element has been discovered and all you know is that it is a noble gas.
   a. Predict the number of electrons in its outer orbit.
      There will be eight electrons in its outer orbit.
   b. Predict its possible atomic number(s).
      The possible atomic numbers of the element are 2, 10, 18, 36.
   c. 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.

8. Using the periodic table on page 22, answer the following questions.
   a. How many energy levels are there in the elements in the third row (period)?

      Elements in the third row have three energy levels.

   b. How many energy levels are there in the elements in the fourth period?

      Elements in the fourth row have four energy levels.

   c. What conclusion can you draw about the periods on the periodic table and the number of energy levels the elements have in that period?

      The number of energy levels seems to match the period number.

9. Why is hydrogen considered a family of one rather than an alkali metal?

   Hydrogen is considered to be a family of one because it can act like a metal in some reactions and like 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

      ii. atomic number?

         The atomic number increases.

      iii. number of protons?

         The number of protons increases.

      iv. number of electrons?

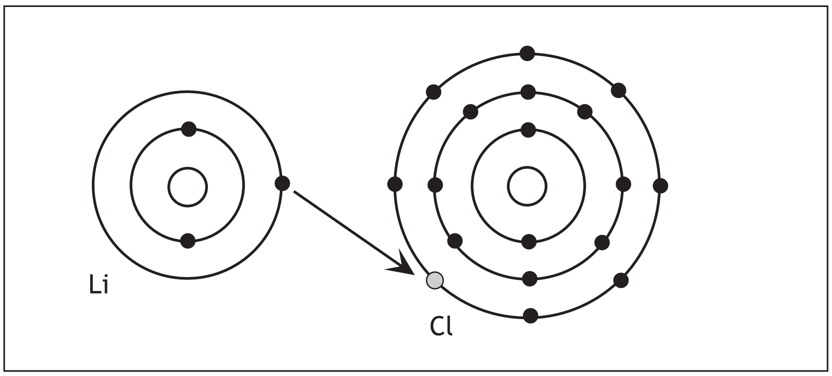
         The number of electrons increases.

Learning Activity 2.5: Ionic Compounds

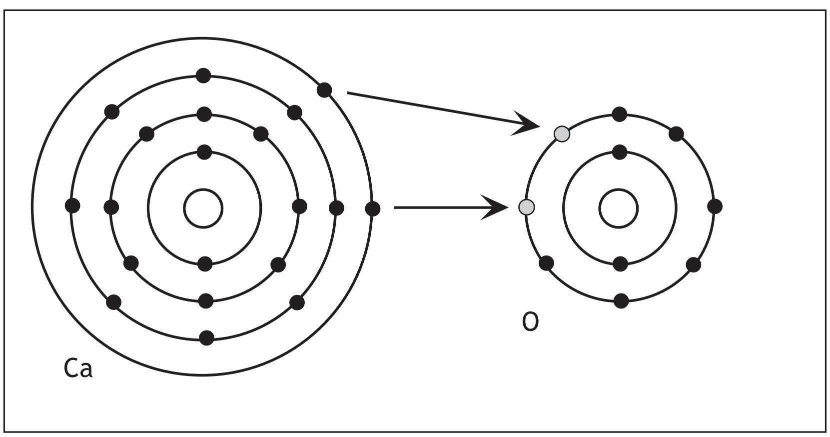
Do the practice questions below to build your skill in writing formulas for ionic compounds.

1. Use Bohr model diagrams to illustrate the compounds formed from the following ions.

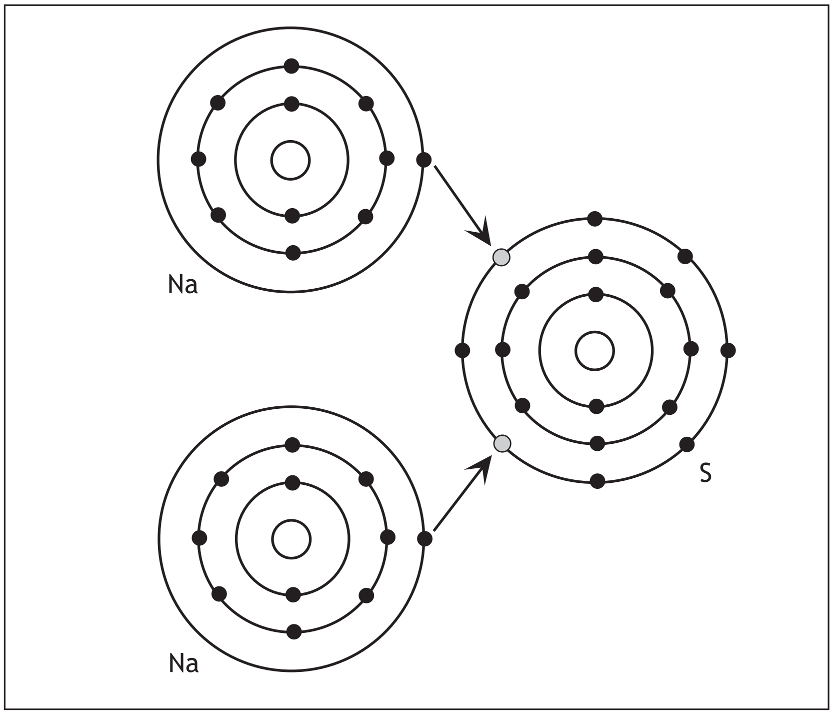
   a. Li^{+1} and Cl^{-1}



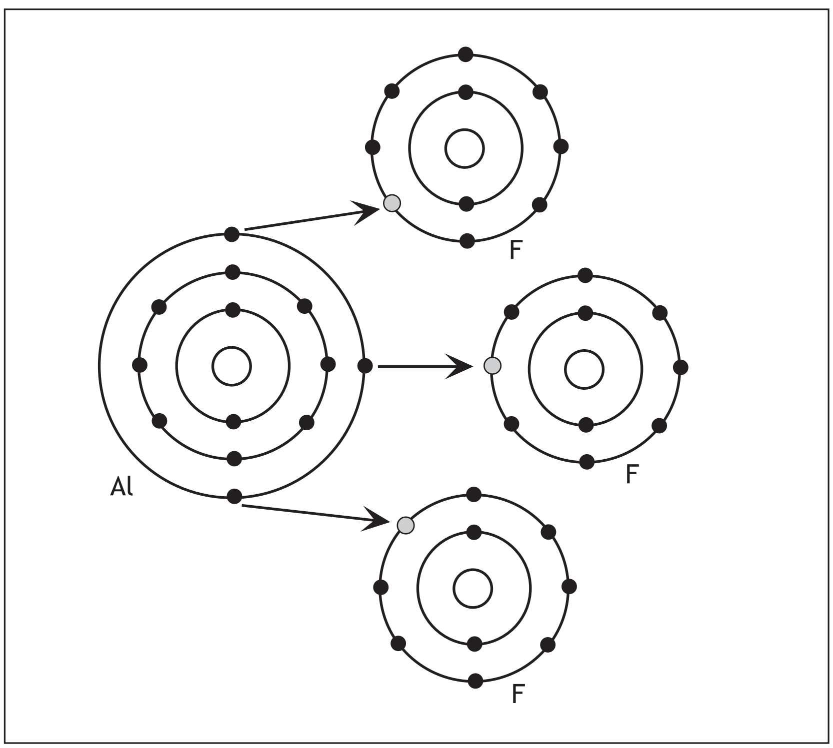
   b. Ca^{+2} and O^{-2}



c. Na^{+1} and S^{-2}

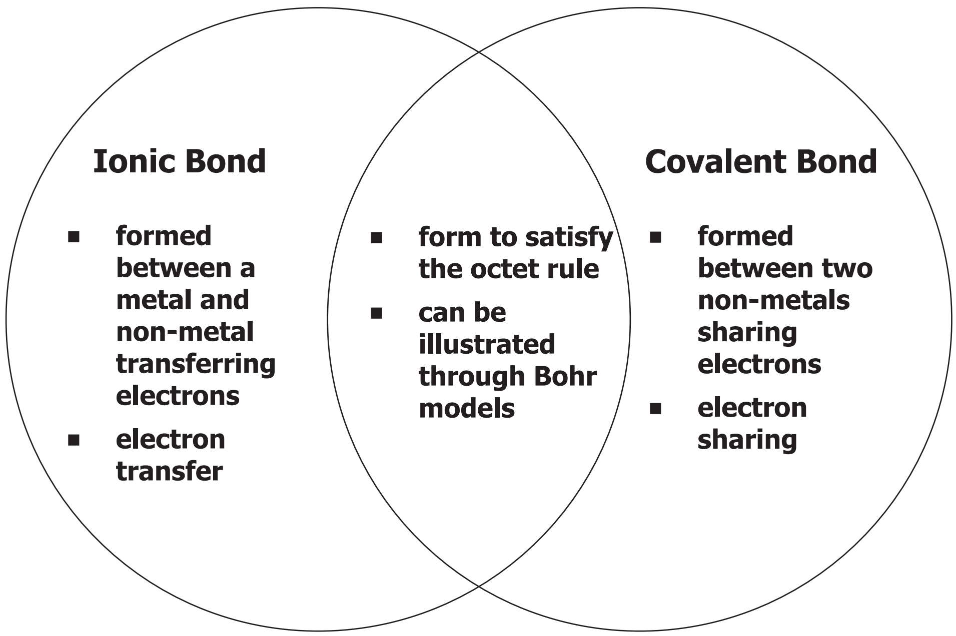


d. Al^{+3} and F^{-1}



Learning Activity 2.6: Forming Covalent Bonds

1. Venn diagrams are concept maps used to compare and contrast two ideas. Each circle represents an idea, and its unique traits are written inside. The area where the circles overlap lists the traits held in common. Complete a Venn diagram showing the similarities and differences between ionic bonding and covalent bonding.



2. What is the octet rule?

   The octet rule states that atoms are stable when the outer orbit contains eight electrons. Hydrogen and helium are exceptions because they need two electrons to achieve stability.

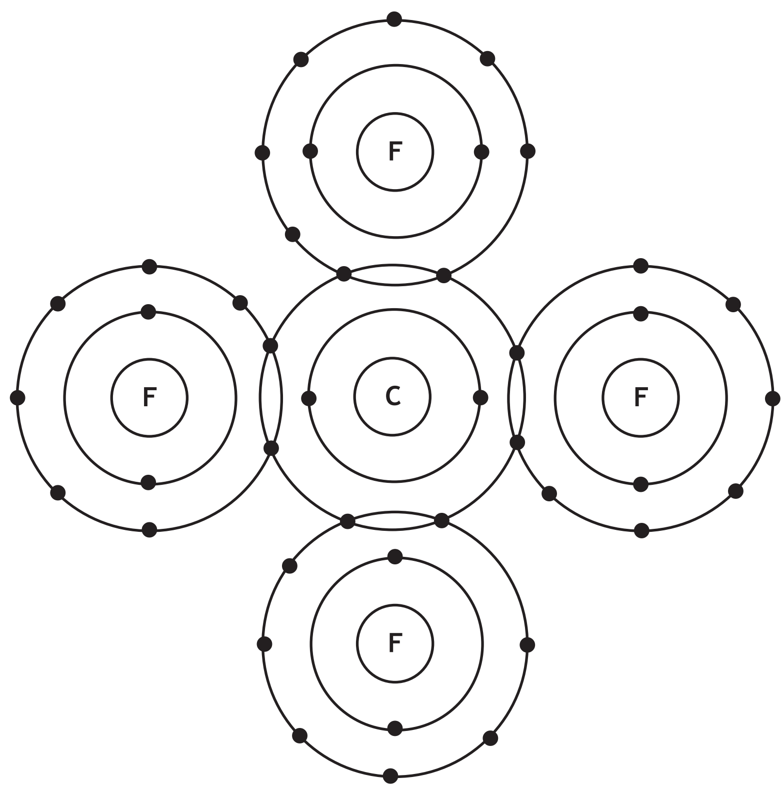
3. What is a diatomic molecule?

   A diatomic molecule is formed by bonding two atoms of the same kind, using a covalent bond.

4. What is the smallest unit of a covalent compound?

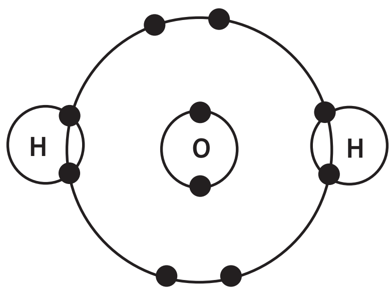
   The smallest unit of a covalent compound is the molecule.

5. A list of pairs of atoms is shown below. Indicate whether each pair would form a compound using an ionic bond or a covalent bond.
   a. calcium and bromine **ionic**
   b. hydrogen and oxygen **covalent**
   c. carbon and oxygen **covalent**
   d. lithium and oxygen **ionic**
   e. phosphorus and chlorine **covalent**
6. Complete the drawings below. One atom of carbon is combining with four atoms of fluorine to form one molecule of a compound.
   a. What kind of bond is used to make the compound?
      Covalent
   b. Place the proper number of electrons in the atoms in their proper orbits.

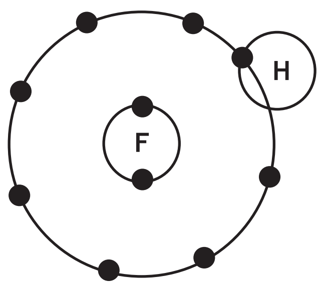


7. Complete the following Bohr diagrams by drawing the remaining hydrogen atoms.

   a. water H_2O



   b. hydrogen fluoride HF



L E S S O N 6

Learning Activity 2.7: Naming Compounds

1. Write formulas for the following compounds that are named using the Stock system.

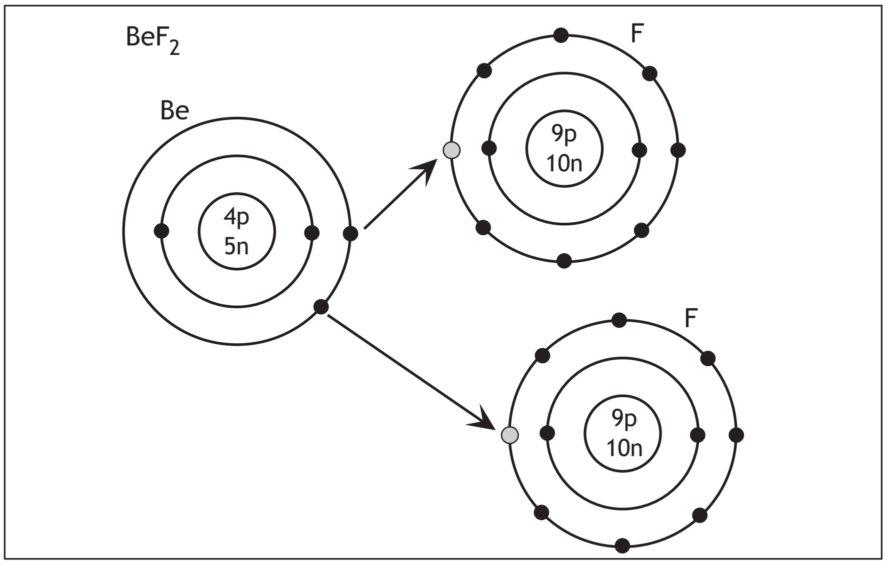
   a. lead (IV) oxide **PbO_2**

   b. iron (III) chloride **$FeCl_3$**

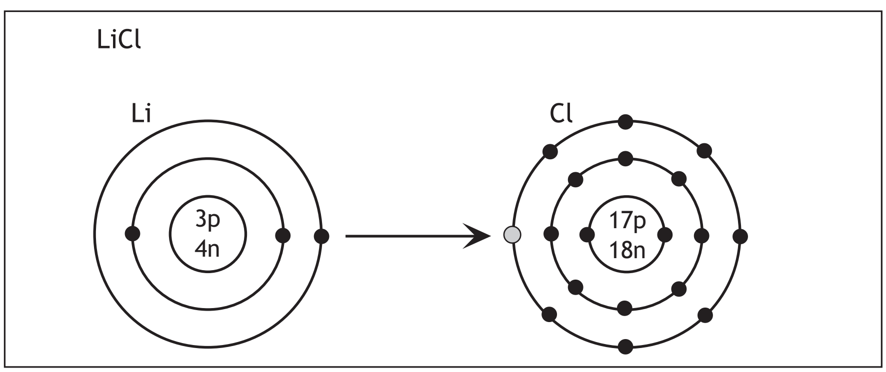
   c. manganese (II) bromide **$MnBr_2$**

   d. bismuth (V) fluoride **BiF_5**

2. Name the following binary compounds.
   a. $CaBr_2$ **calcium bromide**
   b. $HgCl_2$ **mercury (II) chloride**
   c. K_3P **potassium phosphide**
   d. $CuCl_2$ **copper (II) chloride**
   e. ZnS **zinc sulfide**
3. Use Bohr atoms to illustrate the formation of the following compounds.
   a. beryllium fluoride



   b. lithium chloride



4. Write formulas for compounds formed from the following sets of ions.
   a. Li^{+1} and Cl^{-1}
      LiCl
   b. Ca^{+2} and O^{-2}
      CaO

c. Na^{+1} and S^{-2}

Na_2S

d. Al^{+3} and I^{-1}

AlI_3

e. Ba^{+2} and F^{-1}

BaF_2

5. Write formulas for compounds formed from the following elements. (Hint: You will need to look up the combining capacities in the periodic table.)

a. sodium and bromine

NaBr

b. potassium and oxygen

K_2O

c. aluminum and sulfur

Al_2S_3

d. barium and chlorine

$BaCl_2$

e. lithium and oxygen

Li_2O

f. silver and chlorine

AgCl

6. Write formulas for the following compounds.

a. potassium chloride

KCl

b. sodium oxide

Na_2O

c. calcium bromide

$CaBr_2$

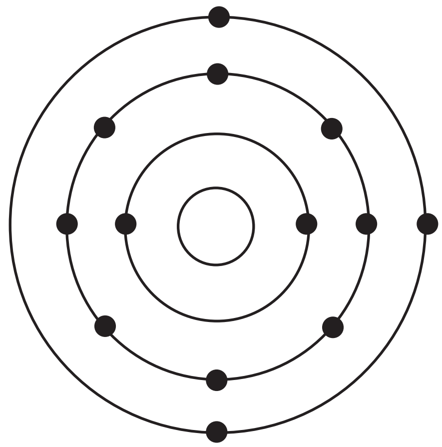
d. magnesium oxide

MgO

e. aluminum fluoride

AlF_3

7. Use the diagram below to answer the following questions.



a. Use the periodic table to name this element.

aluminum

b. To which family does this element belong?

Boron Family (+3)

c. Would you classify this element as a metal or non-metal?

metal

d. How many electrons would you expect this element to lose when it becomes an ion?

three electrons

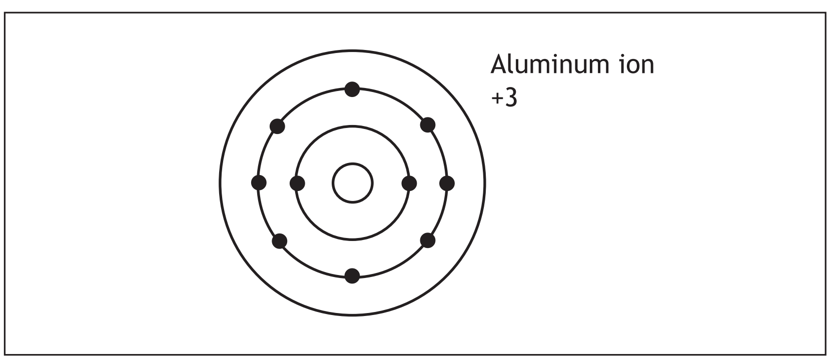
e. What is the charge of this element when it becomes an ion?

+3

f. Would this element be more likely to combine with chlorine or lithium?

chlorine

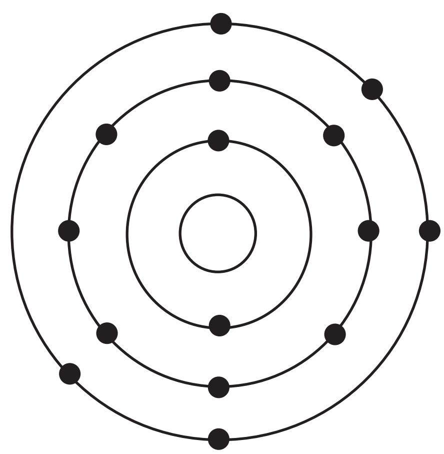
g. Draw the ion that is normally formed from the atom depicted above.



8. Complete this table showing the properties of atoms forming ionic bonds.

Element	Number of Electrons Lost or Gained in an Ionic Bond	Positive or Negative Ion	Charge on Ion
Sulfur	Gains 2	Negative	–2
Boron	Loses 3	Positive	+3
Calcium	Loses 2	Positive	+2
Chlorine	Gains 1	Negative	–1

9. Use the Bohr diagram of the element below to answer the following questions.



a. Use the periodic table to name this element.
   phosphorus
b. To which family does this element belong?
   Nitrogen Family
c. Would you classify this element as a metal or non-metal?
   non-metal
d. How many electrons would you expect this element to gain when it becomes an ion?
   three
e. What is the charge of this element when it becomes an ion?
   –3

f. Would this element be more likely to combine with sodium or calcium?

Sodium, because sodium is more active chemically. It requires one electron only to have inert gas electron configuration.

Lesson 7

Learning Activity 2.8: Names of Covalent Compounds

1. Write formulas for the following element pairs. Use the periodic table for reference.
   a. nitrogen – hydrogen **NH_3**
   b. carbon – chlorine **CCl_4**
   c. nitrogen – bromine **NBr_3**
   d. carbon – oxygen **CO_2**
   e. hydrogen – sulfur **H_2S**
2. Write names for
   a. PBr_3 **phosphorus tribromide**
   b. HF **hydrogen fluoride**
   c. CF_4 **carbon tetrafluoride**
   d. P_2O_3 **diphosphorus trioxide**
3. Write formulas for the following compounds.
   a. phosphorus pentasulfide **PS_5**
   b. nitrogen monoxide **NO**
   c. carbon tetraiodide **CI_4**
   d. nitrogen dioxide **NO_2**
4. Write formulas for the following compounds.
   a. carbon tetrafluoride **CF_4**
   b. nitrogen monoxide **NO**
   c. dinitrogen tetroxide **N_2O_4**
   d. silicon disulfide **SiS_2**

5. Write the names for the following compounds.
   a. H_2S **dihydrogen sulfide**
   b. As_2O_3 **diarsenic trioxide**
   c. CBr_4 **carbon tetrabromide**
   d. OI_2 **oxygen diiodide**
   e. N_2O_4 **dinitrogen tetraoxide**
6. Why is it difficult to write correct formulas for the following compounds: chalk, gasoline, alcohol, and rust?

   It is difficult to write formulas for chalk, gasoline, alcohol, and rust because these are common terms rather than chemical names for the compounds. Chemical names describe the composition of the compound and make it much easier to write formulas for the compounds.
7. a. In what way are ionic and covalent bonds similar?

   Ionic and covalent bonds are similar in that they make use of electrons in the outer orbit when they form a compound.

   b. In what ways are ionic and covalent bonds different?

   Ionic and covalent bonds differ in the behaviour of electrons in the formation of a bond. In ionic bonds there is an electron transfer, and in covalent bonds there is a sharing of electrons.
8. What combining capacity would you expect for each of the following elements?
   a. bismuth **gain three electrons (–3)**
   b. boron **lose three electrons (+3)**
   c. silicon **lose four electrons (+4)**
   d. tellurium **gain two electrons (–2)**
   e. astatine **gain one electron (–1)**
9. a. Is Cs_3N the formula of a covalent compound? **No**

   b. Is C_3N_4 the formula of a covalent compound? **Yes**

   c. How did you make your decision?

   Cesium is a metal. Metals combining with non-metals form ionic bonds. Carbon is a non-metal. Non-metals combining with non-metals form covalent bonds.
10. How can you determine whether a compound is a covalent compound?

    Generally, whenever non-metals combine with non-metals, or whenever identical atoms combine to form diatomic molecules, covalent bonds have been formed.

11. How many atoms of hydrogen combine with each of the following elements to form a covalent compound? When naming the compound, include both the chemical name and the common name where applicable.

	Atoms of Hydrogen	Formula for Compound	Name of Compound
a. carbon	**4**	**CH_4**	**carbon tetrahydride (methane)**
b. boron	**3**	**BH_3**	**boron trihydride**
c. nitrogen	**3**	**NH_3**	**nitrogen trihydride (ammonia)**
d. oxygen	**2**	**H_2O**	**dihydrogen oxide (water)**

LESSON 8

Learning Activity 2.9: Elements and Compounds

1. Which of the following materials are a compound (C) and which are an element (E)?
   a. silver **E**
   b. sugar **C**
   c. propane **C**
   d. steel **C**
   e. molybdenum **E**
   f. iron **E**

2. What elements are used in the following compounds?
   a. ZnO **zinc and oxygen**
   b. BeI_2 **beryllium and iodine**
   c. Ga_2S_3 **gallium and sulfur**
   d. $CnCl_2$ **copernicum and chlorine**

3. Determine the number of atoms of each element in one molecule of the following compounds.
   a. $AlCl_3$ **Al (1) + Cl (3) = 4**
   b. C_3H_8 **C (3) + H (8) = 11**
   c. $C_{11}H_{22}O_{11}$ **C (11) + H (22) + O (11) = 44**

Learning Activity 2.10: Identifying Elements

1. Determine the identity and number of atoms of each element in the given number of molecules or formula units described below.

Compound	Number of Molecules	Element Names	Number of Atoms of Each Element
$KHCO_3$	1 molecule $KHCO_3$	Potassium, Hydrogen, Carbon, Oxygen	K = 1, H = 1, C = 1, O = 3
$AlCl_3$	3 molecules $3AlCl_3$	Aluminum, Chlorine	Al = 3, Cl = 9
CBr_4	6 molecules $6CBr_4$	Carbon, Bromine	C = 6, Br = 24
H_2SO_4	5 molecules $5H_2SO_4$	Hydrogen, Sulfur, Oxygen	H = 10, S = 5, O = 20
$C_{11}H_{22}O_{12}$	4 molecules $4C_{11}H_{22}O_{12}$	Carbon, Hydrogen, Oxygen	C = 44, H = 88, O = 48

2. Locate the combining capacity notation for each family of elements.

Family Name	Combining Capacity
Alkali Metals (Family I)	+1
Alkaline-Earth Metals (Family II)	+2
Halogens	–1
Noble Gases	0

3. Beside each of the formulas, list the elements in the compound and their relative proportions

Formula	Elements and Proportions
a. $BaSO_4$	Ba 1 : S 1 : O 4 (example solution)
b. $NaHCO_3$	**Na 1 : H 1 : C 1 : O 3**
c. $CaSO_4$	**Ca 1 : S 1 : O 4**
d. $LiNO_3$	**Li 1 : N 1 : O 3**
e. H_2SO_4	**H 2 : S 1 : O 4**

4. Using the compound CH_4, calculate the ratio of the number of atoms of hydrogen to the number of atoms of carbon.

Number hydrogen atoms = 4

Number carbon atoms = 1

The ratio = $\dfrac{\textbf{number of atoms of hydrogen}}{\textbf{number of atoms of oxygen}} = \dfrac{4}{1}$

5. Distinguish between an

   a. element and a compound

      An element consists of a single kind of atom and cannot be divided into simpler substances by ordinary chemical reactions.

      A compound is produced when two or more elements combine in specific proportions to form a new material.

      Elements and compounds are both pure substances.

   b. atom and a molecule

      An atom is the smallest particle of an element that can exist by itself.

      A molecule is a particle consisting of two or more atoms joined together.

Learning Activity 2.11: Experiment: Law of Conservation of Mass

1. In Part A, how did the mass of the reactants and flask before the reaction compare to the mass of the reactants and flask after the reaction? Explain.

   The mass before the reaction was greater than the mass after the reaction. Because the Erlenmeyer flask was open, a gas escaped.

2. In Part B, how did the mass of the reactants and flask before the reaction compare to the mass of the reactants and flask after the reaction? Explain.

   The mass before the reaction was equal to the mass after the reaction. The balloon that was placed on the mouth of the Erlenmeyer prevented the gas from escaping.

3. Did your results support the law of conservation of mass? Explain. If not, what sources of error might have affected your results?

   Answers may vary. Possible sources of error could include an improperly calibrated balance, incorrect balance readings, poor seal with the balloon on the flask, too much time taken to place the balloon on the mouth of the flask, balloon propelled off the mouth of the flask.

4. A chemical reaction occurs when one or more substances react to produce one or more new substances. What happened to the reactants? Did they disappear? Were new atoms created when products were formed?

   The reactants were transformed into the products. They did not disappear, but atoms that made up the reactants were rearranged to form the new substances.

5. Can matter be created? destroyed? changed?

   The law of conservation of mass states that matter cannot be created or destroyed, only changed to form new substances with the original atoms.

6. Do gases have a mass? If so, how can their mass be measured?

   Gases do have a mass, but their mass is very small and difficult to measure. Possible ways to answer this question include measuring the mass of an empty container (balloon), re-measuring the container with the gas, and then subtracting the results. Using a gas collection tube is another method of obtaining the mass of gas.

LESSON 10

Learning Activity 2.12: Balancing Equations

1. Balance the following skeleton equations:
   a. $C + S \longrightarrow CS_2$
      $C + 2S \longrightarrow CS_2$
   b. $Al + Cl_2 \longrightarrow AlCl_3$
      $2Al + 3Cl_2 \longrightarrow 2AlCl_3$
   c. $Ba + O_2 \longrightarrow BaO$
      $2Ba + O_2 \longrightarrow 2BaO$
   d. $Na + O_2 \longrightarrow Na_2O$
      $4Na + O_2 \longrightarrow 2Na_2O$
   e. $B + O_2 \longrightarrow B_2O_3$
      $4B + 3O_2 \longrightarrow 2B_2O_3$

2. Write word equations for the equations in Question #1 after you have balanced them.
   a. Carbon and sulfur react to produce carbon sulfide.
   b. Aluminum and chlorine react to produce aluminum chloride.
   c. Barium and oxygen react to produce barium oxide.
   d. Sodium and oxygen react to produce sodium oxide.
   e. Boron and oxygen react to produce boron oxide.

3. Translate the following word equations to balanced chemical equations.
   a. Sodium metal combines with chlorine gas to produce sodium chloride crystals.
      $2Na_{(s)} + Cl_{2(g)} \longrightarrow 2NaCl_{(s)}$
   b. Solid magnesium reacts with hydrogen chloride to produce a magnesium chloride solution and hydrogen gas.
      $Mg_{(s)} + 2HCl_{(l)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$
   c. Potassium iodide reacts with calcium sulfide to produce potassium sulfide and calcium iodide.
      $2KI + CaS \longrightarrow K_2S + CaI_2$
   d. Silver oxide decomposes to produce silver metal and oxygen gas.
      $2Ag_2O_{(s)} \longrightarrow 4Ag_{(s)} + O_{2(g)}$

4. Translate the following chemical equations to word equations.
   a. $Fe_{(s)} + CnS_{(aq)} \longrightarrow FeS_{(aq)} + Cn_{(g)}$
      Iron and copernicum sulfide react to produce iron (II) sulfide and copernicum gas.
   b. $4Fe_{(s)} + 3O_{2(g)} \longrightarrow 2Fe_2O_{3(s)}$
      Iron metal and oxygen gas react to produce solid iron (III) oxide.
   c. $BaF_{2(aq)} + 2LiBr_{(aq)} \longrightarrow BaBr_{2(aq)} + 2LiF_{(aq)}$
      Barium fluoride and lithium bromide react to form barium bromide and lithium fluoride.
   d. $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$
      Gaseous carbon tetrahydride reacts with oxygen gas to produce carbon dioxide and water.
   e. $2MgO_{(s)} \longrightarrow 2Mg_{(s)} + O_{2(g)}$
      Magnesium oxide decomposes to produce magnesium and oxygen.

5. Briefly describe the four steps to balancing a chemical equation.
   a. Determine the number of atoms for each element in the molecules for reactants and products.
   b. If the numbers of atoms on both sides of the equation are equal at this point, the equation is already balanced and you are finished.
   c. Choose the substance that has the most influence on the equation and insert coefficients in the formulas as needed.
   d. Inspect the equation and recalculate the numbers of atoms on both sides of the equation. If they are equal, the equation is balanced. If they are not equal, change the coefficients until the equation is balanced.

6. What name is given to
   a. the materials present before a chemical reaction begins?
      reactants
   b. the materials present after a chemical reaction has taken place?
      products

7. What is the difference between a coefficient and a subscript?
   A coefficient represents the number of molecules and can be changed when balancing an equation. A subscript represents the number of atoms of an element in a molecule of a compound. Subscripts cannot be changed.

8. Why can you change the value of a coefficient but not a subscript when balancing an equation?

   A coefficient represents the number of molecules of a compound involved in a reaction and these can be changed. If a coefficient is changed, the reaction might not go to completion. A subscript describes the structure of a molecule and cannot be changed. If a subscript were changed, the molecule would lose its identity, a new molecule would be formed, and the reaction would be entirely different.

9. What is meant when we say calcium chloride is in an aqueous state?

   If calcium chloride is in an aqueous state, it has been dissolved in water.

Lesson 11

Learning Activity 2.13: Types of Chemical Reactions

1. Balance the practice synthesis questions below.

   a. $Mg + O_2 \longrightarrow MgO$

   $\mathbf{2Mg + O_2 \longrightarrow 2MgO}$

   b. $H_2 + O_2 \longrightarrow H_2O$

   $\mathbf{2H_2 + O_2 \longrightarrow 2H_2O}$

   c. $K + Cl_2 \longrightarrow KCl$

   $\mathbf{2K + Cl_2 \longrightarrow 2KCl}$

   d. $Fe + O_2 \longrightarrow Fe_2O_3$

   $\mathbf{4Fe + 3O_2 \longrightarrow 2Fe_2O_3}$

2. Balance the decomposition practice questions below.

   a. $H_2O \longrightarrow H_2 + O_2$

   $\mathbf{2H_2O \longrightarrow 2H_2 + O_2}$

   b. $MgCl_2 \longrightarrow Mg + Cl_2$

   $\mathbf{MgCl_2 \longrightarrow Mg + Cl_2}$

   c. $FeS \longrightarrow Fe + S$

   $\mathbf{FeS \longrightarrow Fe + S}$

3. Balance the practice double replacement questions below.
   a. $BaF_2 + LiBr \longrightarrow BaBr_2 + LiF$
      $BaF_2 + 2LiBr \longrightarrow BaBr_2 + 2LiF$
   b. $HCl + AlBr_3 \longrightarrow HBr + AlCl_3$
      $3HCl + AlBr_3 \longrightarrow 3HBr + AlCl_3$
   c. $BeF_2 + Na_2O \longrightarrow BeO + NaF$
      $BeF_2 + Na_2O \longrightarrow BeO + 2NaF$
4. Balance the combustion practice problems below.
   a. $C_7H_6O_2 + O_2 \longrightarrow CO_2 + H_2O$
      $2C_7H_6O_2 + 15O_2 \longrightarrow 14CO_2 + 6H_2O$
   b. $Al + O_2 \longrightarrow Al_2O_3$
      $4Al + 3O_2 \longrightarrow 2Al_2O_3$
   c. $C_3H_8 + O_2 \longrightarrow CO_2 + H_2O$
      $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$
5. Balance the following equations:
   a. $Ca + AlCl_3 \longrightarrow CaCl_2 + Al$
      $3Ca + 2AlCl_3 \longrightarrow 3CaCl_2 + 2Al$
   b. $Si + S_8 \longrightarrow Si_2S_4$
      $4Si + S_8 \longrightarrow 2Si_2S_4$
   c. $C_2H_5OH + O_2 \longrightarrow CO_2 + H_2O$
      $C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$
   d. $Cl_2 + NaBr \longrightarrow Br_2 + NaCl$
      $Cl_2 + 2NaBr \longrightarrow Br_2 + 2NaCl$
   e. $N_2 + H_2 \longrightarrow NH_3$
      $N_2 + 3H_2 \longrightarrow 2NH_3$
6. Identify the type of reaction for each example below.
   a. $Fe_{(s)} + CuS_{(aq)} \longrightarrow FeS_{(aq)} + Cu_{(s)}$
      double replacement reaction
   b. $4Fe_{(s)} + 3O_{2(g)} \longrightarrow 2Fe_2O_{3(s)}$
      synthesis reaction
   c. $BaF_{2(aq)} + 2LiBr_{(aq)} \longrightarrow BaBr_{2(aq)} + 2LiF_{(aq)}$
      double replacement reaction
   d. $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$
      combustion reaction

e. $2MgO_{(s)} \longrightarrow 2Mg_{(s)} + O_{2(g)}$
decomposition reaction

7. Complete and balance the following equations.
a. $C_8H_{8(l)} + O_{2(g)} \longrightarrow$ (combustion)
$\mathbf{C_8H_{8(l)} + 10O_{2(g)} \longrightarrow 8CO_{2(g)} + 4H_2O_{(g)}}$ **(combustion)**
b. $Al_{(s)} + I_{2(g)} \longrightarrow$ (synthesis)
$\mathbf{2Al_{(s)} + 3I_{2(g)} \longrightarrow 2AlI_{3(s)}}$ **(synthesis)**
c. $BeF_{2(aq)} + K_2O_{(aq)} \longrightarrow$ (double replacement)
$\mathbf{BeF_{2(aq)} + K_2O_{(aq)} \longrightarrow BeO_{(s)} + 2KF_{(s)}}$
(double replacement)
d. $Cl_{2(g)} + NaBr_{(aq)} \longrightarrow$ (single replacement)
$\mathbf{Cl_{2(g)} + 2NaBr_{(aq)} \longrightarrow 2NaCl_{(s)} + Br_{2(g)}}$
(single replacement)
e. $NaCl_{(l)} \longrightarrow$ (decomposition)
$\mathbf{2NaCl_{(l)} \longrightarrow 2Na + Cl_{2(g)}}$ **(decomposition)**

8. Balance each of the following equations by inserting the proper coefficients where needed.
a. $Mg_{(s)} + O_{2(g)} \longrightarrow MgO_{(s)}$
$\mathbf{2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}}$
b. $HCl_{(aq)} + Zn_{(s)} \longrightarrow H_{(2)} + ZnCl_{2(s)}$
$\mathbf{2HCl_{(aq)} + Zn_{(s)} \longrightarrow H_{(2)} + ZnCl_{2(s)}}$
c. $C_{25}H_{52(s)} + O_{2(g)} \longrightarrow CO_2 + H_2O$
$\mathbf{C_{25}H_{52(s)} + 38O_{2(g)} \longrightarrow 25CO_2 + 26H_2O}$

9. Classify each of the following reactions.
a. $2Fe_{(s)} + O_{2(g)} \longrightarrow 2FeO_{(s)}$
synthesis
b. $Cl_{2(aq)} + 2KBr_{(aq)} \longrightarrow 2KCl_{(aq)} + Br_{2(aq)}$
single displacement
c. $2Ag_2O_{(s)} \longrightarrow 4Ag_{(s)} + O_{2(g)}$
decomposition
d. $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$
combustion

Learning Activity 2.14: Experiment: Acids and Bases

Data Collection:

Part A

Sample	Reaction with RED Litmus Paper	Reaction with BLUE Litmus Paper
Hydrochloric acid	No change	Turns red
Acetic acid	No change	Turns red
Sodium hydroxide	Turns blue	No change
Calcium hydroxide	Turns blue	No change

Part B

Sample	Bromothymol Blue	Phenolphthalein	Universal Indicator
Hydrochloric acid	Turns yellow	No change	Turns red
Acetic acid	Turns yellow	No change	Turns orange-red
Sodium hydroxide	No change	Turns pink	Turns violet
Calcium hydroxide	No change	Turns pink	Turns blue-violet

Part C

Sample	Reaction with Hydrochloric Acid	Reaction with Acetic Acid
Zinc	Strong reaction	Weaker reaction
Magnesium	Strong reaction	Weaker reaction
Iron	Weak reaction	Very weak or no reaction
Copper	No reaction	No reaction

Part D

Household Substances	Red Litmus Paper	Blue Litmus Paper	pH Paper	Bromothymol Blue	Phenolphthalein	Universal Indicator
Lemon juice	No change	Turns red	Red	Turns yellow	No change	Red-orange
Apple	No change	Turns red	Red-orange	Turns yellow	No change	Red-orange
Vinegar	No change	Turns red	Red-orange	Turns yellow	No change	Red-orange
Carbonated drink	No change	Turns red	Orange	Turns yellow	No change	Red-orange
Tomato juice	No change	Turns red	Orange	Turns yellow	No change	Red-orange
Black coffee	No change	Turns red	Orange	Turns yellow	No change	Red-orange
Milk	No change	Turns red	Yellow-green	Turns yellow	No change	Red-orange
Water	No change	No change	Green	No change	No change	No change
Salt water	Turns blue	No change	Green-blue	No change	Turns pink	Blue-purple
Baking soda	Turns blue	No change	Green-blue	No change	Turns pink	Blue-purple
Laundry detergent	Turns blue	No change	Turquoise	No change	Turns pink	Blue-purple
Milk of Magnesia	Turns blue	No change	Blue	No change	Turns pink	Blue-purple
Household ammonia	Turns blue	No change	Blue	No change	Turns pink	Blue-purple
Bleach	Turns blue	No change	Blue	No change	Turns pink	Blue-purple
Drain cleaner	Turns blue	No change	Dark blue	No change	Turns pink	Blue-purple

Data Analysis

Tests	Acid Properties	Base Properties
Red litmus paper	No change	Turns blue
Blue litmus paper	Turns red	No change
pH paper	Red–Orange	Green–Dark Blue
Bromothymol blue	Turns yellow	No change
Phenolphthalein	No change	Turns pink
Universal indicator	Red–Orange	Blue–Purple
Reaction with a metal	Reaction	No reaction

Household Sample	pH Value	Acid or Base
Lemon juice	2	acid
Apple	3	acid
Vinegar	2.5–3.5	acid
Carbonated drink	4	acid
Tomato juice	4	acid
Black coffee	5	acid
Milk	6.5	acid
Water	7	neutral
Salt water	8	base
Baking soda	8	base
Laundry detergent	8	base
Milk of Magnesia	10	base
Household ammonia	11–12	base
Bleach	12.5	base
Drain cleaner	13–14	base

1. Can either red or blue litmus paper be used to identify acids? Explain.

   Either type of litmus paper can be used. Red litmus paper will not change. Blue litmus paper will turn red.

2. How accurate are indicators for measuring pH?

   Indicators usually give a range of pH values, not a precise pH value.

3. What signs of chemical change were observed when acids were placed on metals?

   When acids were placed on most metals, a reaction could be observed. The metal disappeared and a gas and heat were produced.

4. Did all metals react similarly? Explain.

   Not all metals reacted similarly. The iron reacted less than the magnesium or zinc, and the copper did not react at all.

5. List the general properties of acids and bases.

   Acids: pH value is less than 7; stronger acids have lower pH values, react with metals, turn litmus paper red, turn bromothymol blue indicator to yellow, turn universal indicator solution from red to green, and do not react with a phenolphthalein solution.

   Bases: pH value is greater than 7; stronger bases have higher pH values, do not react with metals, turn litmus paper blue, do not react with bromothymol blue, turn universal indicator solution from green to purple, and turn phenolphthalein solution pink.

6. Which of the household substances are acidic? Which are almost neutral? Which are basic?

   See data analysis table. Students should arrive at the following conclusions:

   - **Acids have a pH of less than 7.**
   - **Bases have a pH greater than 7.**
   - **Acids react with metals, but not all react with the same intensity. The strength of the reaction varies with each acid and each metal.**

Learning Activity 2.15: Classifying Acids and Bases

1. State whether the liquids in the following examples illustrate an acid (A) or a base (B).

   a. **A** A liquid is added to zinc and a gas is produced.

   b. **B** A liquid feels slippery between your fingers.

   c. **A** You taste a beverage and it has a pleasant sour taste.

   d. **B** A hairdresser adds a liquid to someone's hair to give it a long-lasting curl.

   e. **B** A liquid is added to colourless phenolphthalein, causing it to turn pink.

   f. **A** A liquid is added to sodium carbonate and a gas is released. The gas will put out a burning splint.

   g. **A** A liquid turns blue litmus paper red.

2. Use the pH values described below to determine whether the substance is neutral, a weak or strong acid, or a weak or strong base.

   a. pH = 12 **strong base**

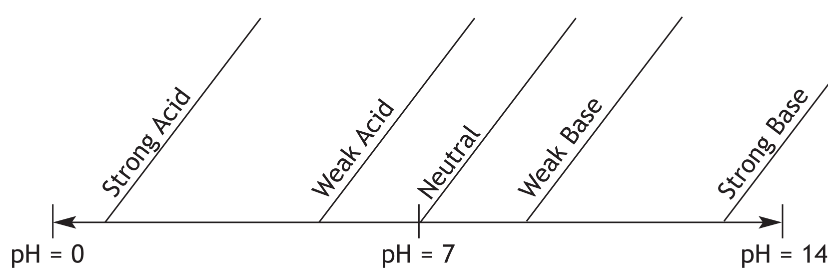
   b. pH = 7 **neutral**

   c. pH = 6 **weak acid**

   d. pH = 9 **weak acid**

   e. pH = 2 **strong acid**

3. Label the line below with the following terms: *strong acid*, *strong base*, *weak acid*, *weak base*, *neutral*.



4. Compare and contrast acids and bases.
   a. How are acids and bases similar?

      Both acids and bases conduct electricity.

   b. How are acids and bases different?

Acids	**Bases**
■ **taste sour**	■ **taste bitter**
■ **turn blue litmus red**	■ **turn red litmus blue**
■ **have a pH between 0 and 6.9**	■ **have a pH between 7.1 and 14**
■ **react with zinc**	■ **will not react with zinc**
■ **react with carbonates to produce CO_2**	■ **are slippery**

5. Use the list of acids and bases below to answer the question. Place the formulas of the acids under the heading "Acid" and the formulas for bases under the heading "Base." If it is not an acid or a base, do not place it under either heading.

NH_4OH	KCl	H_2SO_4	$Mg(OH)_2$	$AlCl_3$	HCl
H_2CO_3	KOH	HNO_3	H_2O	HBr	$Al(OH)_3$

Acid	Base
H_2SO_4 HCl H_2CO_3 HNO_3 HBr	NH_4OH $Mg(OH)_2$ KOH $Al(OH)_3$

6. State whether the following situations involve an acid or a base.
   a. It is added to a base. The products are salt and water.

      acid

   b. It is added to an active metal and a gas is produced.

      acid

   c. It is used as a household cleanser.

      base

   d. It is used to make soft drinks.

      acid

   e. It tastes sour.

      acid

f. It is part of stomach fluids.

   acid

g. It tastes bitter.

   base

7. If you decided you wanted to drink the following, would you be drinking an acid or a base?

   a. milk **acid**

   b. lemonade **acid**

   c. orange juice **acid**

   d. Milk of Magnesia **base**

8. Your mother asks you to bake a cake. She tells you not to forget the baking soda ($NaHCO_3$) and the lemon juice. The reaction is shown below.

   $NaHCO_3$ + lemon juice $\longrightarrow$ sodium compound + H_2O + CO_2

   a. Is lemon juice an acid or a base?

      Lemon juice is an acid.

   b. Why is the lemon juice added to the sodium bicarbonate (baking soda)?

      An acid is needed to produce carbon dioxide from the sodium bicarbonate.

   c. What do you think carbon dioxide has to do with how "light" the cake is?

      Carbon dioxide is responsible for producing the bubbles or air pockets in a cake that cause it to rise and "lighten."

LESSON 13

Learning Activity 2.16: Applications of Acids and Bases

1. The stomach produces its own hydrochloric acid to aid in the digestion of food and yet it doesn't damage itself. Three types of cells—parietal cells, g-cells, and epithelial cells—help in the process of hydrochloric acid production and stomach protection. Describe how your stomach is protected from the acid it produces.

   The stomach is protected by the epithelial cells, which produce and secrete a bicarbonate-rich solution that coats the mucosa. Bicarbonate is alkaline—a base—and neutralizes the acid secreted by the parietal cells, producing water in the process. This continuous supply of bicarbonate is the main way that your stomach protects itself from autodigestion (the stomach digesting itself) and the overall acidic environment.

2. The stomach produces its own hydrochloric acid and has its own mechanism for protection. The small intestine cannot manage such low pH material. How does your body raise the pH of the fluid entering the small intestine?

   The pancreas supplies the small intestine with sodium bicarbonate ($NaHCO_3$). This base will neutralize the acidic stomach fluids so they will not damage the small intestine.

3. Name three ways that sulfuric acid is used as an aid in industrial production.

   Any three of the following:

   - **production of fertilizers**
   - **in the manufacture of other chemicals**
   - **petroleum refining**
   - **in cleaning metals (pickling)**
   - **production of rayon**
   - **lead-storage batteries**

4. Name at least two WHMIS and two HHPS symbols that could be used with sulfuric acid as hazard alerts.

   Answers will vary.

5. Name the common fertilizer chemical used by farmers to provide nitrogen for plants.

   Ammonium nitrate is the most common form of fertilizer used for crop production.

6. What common explosive is produced from nitric acid?

   Sulfuric acid is used in the production of TNT (trinitrotoluene).

7. State whether the following household chemicals contain acids or bases. If you know the name of acid or base, include it in your answer.

   a. soap **base**
   b. drain cleaner **base**
   c. pickle juice **acid**
   d. antacid **base**
   e. baking powder **base**
   f. window cleaner **base**

8. What property of bases makes them good window cleaners?

   Bases dissolve proteins and fats. Since most windows have fingerprints on them, window cleaners will clean a window by dissolving the fingerprints.

9. What is heartburn and why is an antacid used to help deal with it?

   Heartburn occurs when some stomach fluid moves into the esophagus, causing a burning pain. An antacid is a base that neutralizes the acid in stomach fluid, thereby reducing the discomfort.

10. Why can pickles be left for a long time in a refrigerator without spoiling?

    Pickles contain acetic acid that, if it is at proper concentration, will destroy bacteria.

11. What is the basic difference and what is the basic similarity between a baking powder and baking soda?

    Baking powder contains its own acid when it is mixed with water, whereas baking soda must have an acid such as lemon juice added. Baking powder and baking soda both use sodium bicarbonate to produce carbon dioxide.

12. If you forgot to include baking powder in your cake, what would be the result?

    If I forgot to include baking powder in my cake, it would be very flat!

LESSON 14

Learning Activity 2.17: Analyzing Equations

$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O$

1. Name the reactants and products in this reaction.
   a. Reactants
      hydrochloric acid and sodium hydroxide
   b. Products
      sodium chloride and water
   c. What does the subscript *(aq)* mean?
      The subscript (aq) means aqueous solution. The sodium hydroxide has been dissolved in water.
   d. Name a compound that shows a subscript value.
      Water has a subscript following the H.
   e. How many molecules of each compound below are used or produced in the reaction?
      i. sodium hydroxide **1 molecule**
      ii. water **1 molecule**

2. Balance the following chemical equations.
   a. $Ca + S \longrightarrow CaS$
      $\mathbf{Ca + S \longrightarrow CaS}$
   b. $HCl + NaOH \longrightarrow NaCl + H_2O$
      $\mathbf{HCl + NaOH \longrightarrow NaCl + H_2O}$
   c. $Na + H_2O \longrightarrow NaOH + H_2$
      $\mathbf{2Na + 2H_2O \longrightarrow 2NaOH + H_2}$
   d. $CH_4 + O_2 \longrightarrow CO_2 + H_2O$
      $\mathbf{CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O}$

Learning Activity 2.18: Neutralization

Balance the neutralization reactions shown below. Name each of the compounds (except water) in each equation.

1. HBr + KOH ⟶ KBr + H_2O

   HBr + KOH ⟶ KBr + H_2O

   hydrogen bromide + potassium hydroxide ⟶ potassium bromide + water

   (no balancing required)

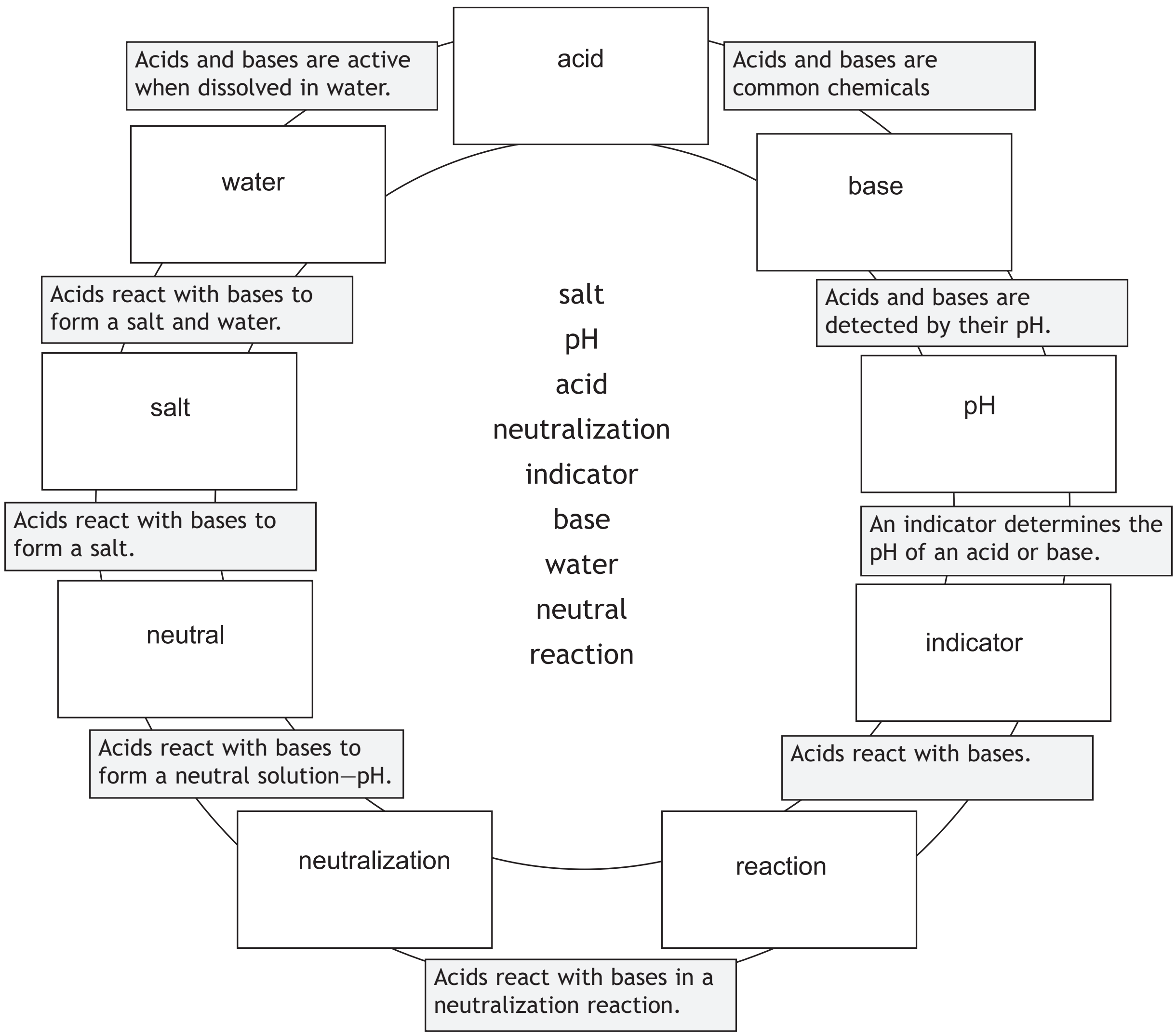
2. HI + NaOH ⟶ NaI + H_2O

   HI + NaOH ⟶ NaI + H_2O

   hydrogen iodide + sodium hydroxide ⟶ sodium iodide + water

   (no balancing required)

3. Read the list of words in the circle. Select one word and place it in any unshaded rectangle. In the next unshaded rectangle, place another word that is related to the first. Plan ahead; the last few words will be tricky to place. You may wish to add some linking comments in the shaded rectangle between words to make the ideas flow better.



4 A double replacement reaction in general form is shown below.

AB + CD ⟶ AD + CB

Use the neutralization reaction between hydrochloric acid and sodium hydroxide to illustrate how a neutralization reaction is a double displacement reaction.

HCl + NaOH ⟶ NaCl + H_2O

Hydrogen from HCl combines with oxygen in NaOH for one displacement, and chlorine from HCL combines with sodium in NaOH to form NaCl in the second displacement.

5. Why are a salt and water always formed in a neutralization reaction?

   The double displacement reaction allows only the positive metal ion from the base to combine with the negative ion from the acid.

LESSON 15

Learning Activity 2.19: Air Pollution

1. Nickel smelter operations in Sudbury, Ontario, release sulfur as sulfur dioxide gas in the refining process, as shown in the equation below.

   $NiS + O_2 \longrightarrow Ni + SO_2$

   a. What is the metal being refined, according to the equation?

      nickel

   b. What pollutant is formed in the reaction?

      sulfur dioxide (SO_2)

   c. What acid do you think may be formed from the refining process after the SO_2 goes up the smokestack into the atmosphere?

      H_2SO_3

2. If you have access to the Internet, access the Manitoba Government's environmental conservation website: www.gov.mb.ca/conservation/environmental.html. Click on the "Information Brochure and Reports" link under Air Quality. From there, select the report on "Flin Flon and Sulfur Dioxide: Effects on People and the Environment." Based on the information in this report, answer the following questions:

   a. What type of pollutant is being monitored in Flin Flon?

      Sulfur dioxide is being monitored in Flin Flon.

b. Briefly describe the health hazards from this pollutant.

Sulfur dioxide irritates the nose and throat. Effects on healthy individuals include an increased breathing rate or an increased resistance to airflow.

For longer exposures, sulfur dioxide levels above 0.15 ppm have been linked with increased hospital admissions for cardiac or respiratory illnesses.

c. Briefly describe the environmental hazards from this pollutant.

Leaves and needles are damaged.

d. What is the source of pollution in Flin Flon?

The metallurgical smelter operated by the Hudson Bay Mining and Smelting Company in Flin Flon accounts for about 49 percent of the province's human-made emissions of sulfur dioxide into the atmosphere.

e. When is a level 1 public warning initiated in Flin Flon?

A level 1 public warning is issued when any two consecutive, 15-minute-average sulfur dioxide concentrations are greater than 0.34 ppm.

f. What is recommended that you do if you feel discomfort?

Remain indoors with the windows closed.

Use a fan or air conditioner to circulate air.

Refrain from smoking and avoid second-hand smoke.

Avoid unnecessary physical exertion.

Call your physician or hospital if you develop a cough or difficulty in breathing.

g. How is the pollution problem being dealt with in Flin Flon?

The Hudson Bay Mining and Smelting Company in Flin Flon operates a public air quality warning system based on the air quality objectives. This system advises residents when elevated levels of sulfur dioxide are present in the community.

3. a. What two oxides are responsible for acid rain?

Sulfur and nitrogen oxides cause acid rain.

b. What forms of precipitation, other than rain, are there?

There are acid snow, fog, or dust.

c. Why is acid rain more of a problem in eastern Canada than in western Canada?

Acid rain is a problem in eastern Canada because many of the water and soil systems in this region lack natural alkalinity—such as a lime base—and therefore cannot neutralize acid naturally.

4. a. What is smog?

The term *smog* was coined more than three decades ago to describe a mixture of smoke and fog in the air. Today, smog refers to a noxious mixture of air pollutants that can often be seen as a haze in the air.

b. Why is smog a health concern?

Smog can make breathing more difficult—even for healthy people—and it can make us more susceptible to cardiopulmonary diseases. Even healthy young adults breathe less efficiently on days when the air is heavily polluted, especially if they are exercising outdoors. Particularly vulnerable to smog are people with heart or lung disease, the elderly, and small children.

c. Describe the two kinds of smog and their origins.

London-type smog (sulfur dioxide smog) comes from burning coal in fog.

Los Angeles–type smog (photochemical) comes from vehicle pollution and temperature inversion.

5. a. From where does ground-level ozone come?

Human activities are responsible for the increases in ground-level ozone in recent years. About 95 percent of nitrogen oxides from human activity come from the burning of coal, gas, and oil in motor vehicles, homes, industries, and power plants. VOC come mainly from gasoline combustion and from the evaporation of liquid fuels and solvents.

b. What harmful effects result from ground-level ozone?

Ozone not only affects human health, it can damage vegetation and decrease the productivity of some crops. It can also injure flowers and shrubs, and may contribute to forest decline in some parts of Canada. Ozone can also damage synthetic materials, cause cracks in rubber, accelerate fading of dyes, and speed deterioration of some paints and coatings. As well, it damages cotton, acetate, nylon, polyester, and other textiles.

c. What is the chemical formula for ozone?

Ozone is a form of oxygen. The oxygen we breathe is in the form of oxygen molecules (O_2)—two atoms of oxygen bound together. Ozone, on the other hand, consists of three atoms of oxygen bound together (O_3). Ozone is a bluish gas and has a very harsh odour.

d. What is an important physical property of ozone?

Ozone is capable of blocking some UV and most other harmful radiation from the Sun.

e. Where is the ozone layer located?

Approximately 90 percent of all ozone is produced naturally in the stratosphere. While ozone can be found throughout the entire atmosphere, the greatest concentration occurs at an altitude of about 25 kilometres. This band of ozone-rich air is known as the ozone layer.

f. What is the leading cause of ozone depletion?

The compounds that contain only chlorine, fluorine, and carbon are called chlorofluorocarbons, usually abbreviated as CFCs. CFCs, carbon tetrachloride, and methyl chloroform are important human-produced ozone-depleting gases that have been used in many applications, including refrigeration, air conditioning, foam blowing, cleaning of electronics components, and as solvents. Another important group of human-produced halocarbons is the halons, which contain carbon, bromine, fluorine, and (in some cases) chlorine, and have been mainly used as fire extinguishants.

LESSON 16

Learning Activity 2.20: Technology Recap

1. State the three basic categories in which clean coal technologies take place, and briefly explain how they work.

   a. Pre-combustion technologies—use chemical and biological technologies to remove sulfur before the coal is burned.

   b. Combustion technologies—remove pollutants while the coal burns. Fluidized-bed combusters hold promise.

   c. Post-combustion technologies—focus on the flue gases emitted from the stack. Scrubbers are successful in removing sulfur and sulfur compounds.

2. How does a catalytic converter in a car reduce pollution?

   A catalytic converter is able to take the exhaust from a car or truck and pass it through a chamber filled with ceramic beads coated with catalysts. These catalysts oxidize carbon monoxide (CO) and reduce nitrogen oxides to nitrogen.

3. Why do you think our government is promoting the use of gasohol?

   There are advantages to gasohol:

   - **Gasohol reduces the amount of dependence on fossil fuels.**
   - **Gasohol provides a value-added market for agriculture produce.**
   - **Gasohol provides an opportunity for technological development in Manitoba.**

Grade 10 Science (20F)

Practice Midterm Examination

GRADE 10 SCIENCE

Practice Midterm Examination

Name: ______________________________

Student Number: ______________________________

Attending ❑ Non-Attending ❑

Phone Number: ______________________________

Address: ______________________________

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For Marker's Use Only

Date: ______________________________

Final Mark ________ /100 = ________%

Comments:

Instructions

- You have a maximum of 2.5 hours to write this exam.
- Supplies required: pencil or pen, eraser, paper—you are permitted to bring a calculator, but it is not required
- This exam covers course material from Modules 1 and 2.
- This exam is worth 20 percent of your final mark.

Part A: Dynamics of Ecosystems

Section 1: Multiple Choice

Choose the best answer. Each question is worth one mark. This section of the midterm exam is worth 20 marks.

1. The relationship between a producer and a primary consumer is best illustrated by
   a. sheep eating grass
   b. wolves eating a moose
   c. mushrooms growing on rotting logs
   d. leaves growing on trees

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2. Denitrification is defined as
   a. the conversion of nitrate and ammonia into plant proteins
   b. the cycling of nitrogen through an ecosystem
   c. the conversion of nitrate and ammonia into nitrogen gas
   d. the removal of nitrogen from the atmosphere

3. In a predator-prey relationship, an increase in the predator population is usually followed by
   a. an increase in the damage to the environment by the prey
   b. an decrease in the prey population
   c. an increase in the birth rate of the prey
   d. starvation of the prey

4. Which of the following is abiotic?
   a. water
   b. bacteria
   c. grass
   d. a skunk

5. A species is _________ when it is in danger of disappearing from the area in which it lives.
   a. extinct
   b. threatened
   c. endangered
   d. extirpated

6. The increase in the concentration of toxins along each level of a food chain is known as
   a. bioaccumulation
   b. biogeochemical
   c. biotoxification
   d. biocarcinogenics

Name: ______________________________

7. A rabbit eats grass, and a fox eats the rabbit. In this food chain, the fox is a
   a. producer
   b. primary consumer
   c. secondary consumer
   d. scavenger

8. Which process does ***not*** directly affect the carbon cycle?
   a. ammonia levels in soil
   b. the eruption of a volcano
   c. algal blooms
   d. deforestation

9. Which statement is ***true*** for a pyramid of energy?
   a. Primary consumers contain the greatest amount of energy.
   b. The pyramid represents the total amount of living material per tropic level.
   c. The least amount of energy is within the producers.
   d. Less energy is available to organisms higher up the pyramid.

10. How do bacteria contribute to the nitrogen cycle?
   a. They are not involved in the nitrogen cycle.
   b. They allow primary consumers to use atmospheric nitrogen.
   c. They are responsible for nitrogen fixation.
   d. They absorb excess nitrogen gas from the atmosphere.

11. Which level of a food chain is at greatest risk due to the bioaccumulation of toxins?
   a. producers
   b. primary consumers
   c. secondary consumers
   d. tertiary consumers

12. Algal blooms are most likely to occur during
   a. spring
   b. summer
   c. autumn
   d. winter

13. A decomposer is
    a. an organism that eats plants
    b. a dead organism
    c. an organism that breaks down dead matter and waste
    d. an organism that lives inside a host organism and eats the host

14. The variety of organisms found within an ecosystem is known as its
    a. sustainability
    b. food web
    c. population dynamics
    d. biodiversity

15. Carrying capacity refers to
    a. the largest population of a species that a particular environment can support
    b. the greatest amount of biodiversity that a particular environment can support
    c. the largest size of predators that a particular environment can support
    d. the maximum number of plant species that a particular environment can support

16. If population growth is greater than zero, then the following is ***true***:
    a. There are more deaths and emigrants than there are births and immigrants in a population.
    b. The size of the population begins to decrease.
    c. There are more births and immigrants than there are deaths and emigrants in a population.
    d. The size of a population remains the same.

17. A tree produces acorns, and a squirrel eats the acorns. The squirrel dies and crows eat its dead body. In this food chain, the crows are defined as
    a. scavengers
    b. secondary consumers
    c. tertiary consumers
    d. decomposers

18. How did human use of DDT affect predatory birds such as the peregrine falcon?
    a. Falcons ingested the pesticide through their food.
    b. The pesticide caused the birds to lay eggs with thin, brittle shells.
    c. DDT affected the birds' behaviour, causing them to abandon their nests.
    d. All of the above.

Name: ____

19. Which of these is ***not*** a producer?
    a. a tomato plant
    b. a pine tree
    c. a mushroom
    d. a dandelion

20. Why is the spread of zebra muscles a concern in Canada?
    a. The species has few natural predators in North America.
    b. They remove large quantities of plankton and algae from aquatic ecosystems.
    c. They are capable of reproducing in large numbers.
    d. All of the above.

Section 2: Explain

Answer the following questions in complete sentences. The mark allocations are provided for each question. This section of the midterm exam is worth 30 marks.

1. Describe the carbon cycle. You may use a diagram to help your explanation. (*3 marks*)

2. Hannah has studied a population of elk in northern Manitoba over the last decade, and she noticed that the herd has never grown over a hundred members. What factors may have limited the growth of this population? (*6 marks*)

3. Kingsley is a farmer who grows canola. Recently, a salesperson has been visiting Kingsley's farm to advertise a new fertilizer spray made of pure nitrogen gas (N_2). By spraying his crops with this new gaseous fertilizer, the salesperson claims that Kingsley will be able to grow healthy crops in an environmentally responsible manner.

   a. Why do plants such as canola need nitrogen? (*1 mark*)

   b. Do you think this fertilizer is a good investment? Use your knowledge of the nitrogen cycle to explain your reasoning. (*3 marks*)

Name: ____

4. Kingsley's neighbour, Elizabeth, grows corn. In previous years, Elizabeth has lost many of her crops due to worms. This season, Elizabeth sprays her crops with a brand-new pesticide to get rid of the worms. Over the summer, Elizabeth notices dozens of dead sparrows in her corn field, each body surrounded by buzzing flies.

   a. Identify the food chain in Elizabeth's corn field. Label each trophic level. (*4 marks*)

   ____

   ____

   ____

   ____

   b. Why are the sparrows dying? Suggest two reasons. (*4 marks*)

   ____

   ____

   ____

   ____

5. What is biodiversity, and how does it benefit an ecosystem? (*3 marks*)

   ____

   ____

   ____

6. Use the table below to answer the following questions.

Year	Wolf Population	Deer Population
1991	20	4000
1992	24	4600
1993	33	5000
1994	44	4800
1995	56	4500
1996	48	4200
1997	42	3900
1998	36	3850
1999	38	3900
2000	38	3950

a. How would you describe the relationship between the wolf population and the deer population? (*2 marks*)

____

____

____

b. How did the deer population change between 1993 and 1997? What might have caused this change? (*4 marks*)

____

____

____

____

Name: ____

Part B: Chemistry

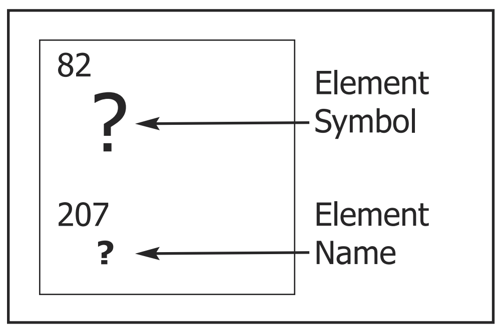
Section 1: Multiple Choice

Choose the best answer. Each question is worth one mark. This section of the midterm exam is worth 25 marks.

A copy of the Periodic Table of Elements is available at the end of this exam booklet.

1. An atom of barium has an atomic number of 56 and an atomic mass of 137u. What is the total number of protons and neutrons in one atom of barium?
   a. 56
   b. 81
   c. 137
   d. 193

2. The diagram below shows the atomic number and atomic mass of an element. Identify that element.
   a. Ga (gallium)
   b. Sb (antimony)
   c. Pb (lead)
   d. Po (polonium)



3. Sulphur is a member of which family?
   a. chalcogens
   b. halogens
   c. noble gases
   d. hydrogen

4. Which of the following ions would form a stable ionic compound with a single ion of iodide (I^-)?
   a. Na^+
   b. $Mg2^+$
   c. Cl^-
   d. Ar
5. What process takes place whenever a covalent bond is formed?
   a. proton transfer
   b. electron transfer
   c. proton sharing
   d. electron sharing
6. Which of the elements listed must bond with four atoms of hydrogen in order to fill its valence shell?
   a. B
   b. C
   c. N
   d. O
7. Which of the following compounds is an example of a diatomic molecule?
   a. H_3O
   b. NH_4
   c. Cl_2
   d. HBr
8. If calcium and oxygen were to form a stable ionic compound, which of the following chemical formulas would best represent that compound?
   a. CaO
   b. CaO_2
   c. Ca_2O
   d. CaO_3

Name: ______________________________

9. An ionic bond forms when
   a. a noble gas combines with a halogen
   b. a metal combines with a non-metal
   c. an alkali metal gains an electron
   d. a chalcogen combines with hydrogen

10. Carbon and chlorine combine to form
   a. a covalent compound
   b. an ionic compound
   c. a strong acid
   d. carbon dichloride

11. Compound X is a newly discovered acid. Which statement best describes the properties of compound X?
   a. It feels slippery when touched.
   b. It reacts with many metals.
   c. It turns red litmus paper blue.
   d. All of the above.

12. Complete the following neutralization reaction:

$$\_\_\_\_\_\_ + NaOH \rightarrow Na_2CO_3 + H_2O$$

   a. $C(OH)_4$
   b. CH_2O_3
   c. H_2CO_3
   d. CO_2

13. Which of the following chemical reactions is a single replacement reaction?
   a. $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$
   b. $Ca + AlCl_3 \rightarrow CaCl_2 + Al$
   c. $NaBr + KI \rightarrow KBr + NaI$
   d. $Ca^{+2} + 2F^{-} \rightarrow CaF_2$

14. In the chemical reaction below, which compound is a salt?

$$HCl + Ca(OH)_2 \rightarrow H_2O + CaCl_2$$

   a. HCl
   b. $Ca(OH)_2$
   c. H_2O
   d. $CaCl_2$

15. What change is required to balance the following reaction?

$$Mg(OH)_2 + H_2S \rightarrow MgS + H_2O$$

   a. Double the amount of magnesium hydroxide reacted.
   b. Double the amount of hydrogen sulfide reacted.
   c. Double the amount of magnesium sulfide produced.
   d. Double the amount of dihydrogen monoxide produced.

16. What pH is considered neutral?
   a. 9.5
   b. 7.0
   c. 5.3
   d. 3.0

17. Pickles are cucumbers soaked in acetic acid. Acetic acid is best categorized as
   a. a strong base
   b. a weak base
   c. a weak acid
   d. a strong acid

18. What compound does the pancreas use to help neutralize fluid leaving the stomach?
   a. sulfuric acid
   b. sodium bicarbonate
   c. citric acid
   d. calcium hydroxide

Name: ____

19. What two groups of chemicals are responsible for the formation of acid rain?
    a. carbon monoxide and carbon dioxide
    b. chlorofluorocarbons and halons
    c. methane and gasoline
    d. sulfur oxides and nitrogen oxides

20. Which property of bases makes them useful as household cleaners?
    a. their ability to conduct electricity
    b. their ability to dissolve fats and proteins
    c. their ability to not react with metals
    d. their bitter taste

21. Which equation represents a neutralization reaction?
    a. $HCl + LiOH \rightarrow LiCl + H_2O$
    b. $Ca + S \rightarrow CaS$
    c. $CH_4 + O_2 \rightarrow CO_2 + H_2O$
    d. $4Cu + O_2 \rightarrow 2Cu_2O$

22. How does ozone contribute to human life on Earth?
    a. Ozone reduces the occurrence of acid rain.
    b. In the upper atmosphere, ozone filters harmful radiation from the Sun.
    c. Ozone breaks down harmful smog in the lower atmosphere.
    d. It is not useful at all and, in fact, causes lung damage in children.

23. What type of reaction is illustrated below?

    $$2Hg + O_2 \rightarrow 2HgO$$

    a. synthesis reaction
    b. decomposition reaction
    c. combustion reaction
    d. single replacement reaction

24. The Montreal Protocol is an international agreement designed to
    a. ban the use of chlorofluorocarbons (CFCs)
    b. reduce industrial greenhouse gas emissions
    c. protect Canada's arctic wildlife
    d. eliminate the use of bisphenol-A in plastic products

25. How does a catalytic converter help reduce air pollution?
    a. A catalytic converter is used in post-combustion reduction of sulfur in industry.
    b. A catalytic converter is used to increase the efficiency of a car's combustion engine.
    c. A catalytic converter reduces nitrogen oxide emissions in vehicles.
    d. A catalytic converter is used to scrub impurities such as sulfur and ash from coal.

Section 2: Explain

Answer the following questions in complete sentences. The mark allocations are provided for each question. This section of the midterm exam is worth 25 marks.

1. List the four categories of clean coal technologies and briefly explain how they work. (*8 marks*)

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Name: ____

2. The combustion engine inside a car burns hydrocarbons in order to produce the mechanical energy that will move the vehicle. The skeleton chemical equation for the combustion of gasoline is written as follows:

$$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O + \text{energy}$$

If carbon dioxide and water are the only chemical products created in a car's combustion reaction, explain how cars are able to emit nitrogen oxides (such as NO and NO_2). (*2 marks*)

____

____

____

3. Write a balanced chemical equation for the following reactions. Identify the type of reaction occurring.

a. Barium fluoride and lithium bromide react to produce barium bromide and lithium fluoride. (*2 marks*)

____

____

____

b. The process of electrolysis splits water into hydrogen gas and oxygen gas. (*2 marks*)

____

____

____

c. Solid potassium and chlorine gas combine to form potassium chloride. (*2 marks*)

____

____

____

4. Write word equations for the following chemical reactions. (*2 marks each x 3 = 6 marks*)
   a. $Ba + O_2 \rightarrow BaO$

   ____

   ____

   ____

   b. $AlCl_3 \rightarrow Al + Cl_2$

   ____

   ____

   ____

   c. $CH_4 + O_2 \rightarrow CO_2 + H_2O$

   ____

   ____

   ____

5. Acids and bases are commonly used in our homes, in industrial settings, and even in our bodies. Select specific acids or bases from the following list, and describe three ways that they may be used. You may describe three uses for one chemical, or a single use for three different chemicals. (*3 marks*)
   - sulfuric acid (H_2SO_4)
   - nitric acid (HNO_3)
   - hydrochloric acid (HCl)
   - sodium bicarbonate ($NaHCO_3$)
   - citric acid
   - ammonium hydroxide (NH_4OH)
   - sodium hydroxide (NaOH)
   - aluminum hydroxide ($Al[OH]_3$)

   ____

   ____

   ____

   ____

   ____

   ____

The Periodic Table of the Elements

Key: Atomic number → 6; Symbol → C; Carbon; 12.0 ↑ Atomic mass*; +4 +2 } Combining capacity or Valence number

*Based on C^{12} = 12.00000

Each cell: atomic number, symbol, name, atomic mass, combining capacity (valence).

Groups 1 and 2: Alkali Metals (1, from Li down) and Alkaline-Earth Metals (2). Groups 3–12: Transition Metals. Groups 13–17: Non-Metals. Group 18: Noble Gases.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.0 ±1																	2 He Helium 4.0
3 Li Lithium 6.9 +1	4 Be Beryllium 9.0 +2											5 B Boron 10.8 +3	6 C Carbon 12.0 +4 +2	7 N Nitrogen 14.0 −3 +5	8 O Oxygen 16.0 −2	9 F Fluorine 19.0 −1	10 Ne Neon 20.2
11 Na Sodium 23.0 +1	12 Mg Magnesium 24.3 +2											13 Al Aluminum 27.0 +3	14 Si Silicon 28.1 +4 +2	15 P Phosphorus 31.0 −3	16 S Sulphur 32.1 −2 +4 +6	17 Cl Chlorine 35.5 −1	18 Ar Argon 40.0
19 K Potassium 39.1 +1	20 Ca Calcium 40.1 +2	21 Sc Scandium 45.0 +3	22 Ti Titanium 47.9 +3 +4	23 V Vanadium 50.9 +2 +5	24 Cr Chromium 52.0 +2 +3 +6	25 Mn Manganese 54.9 +2 +7	26 Fe Iron 55.8 +3 +2	27 Co Cobalt 58.9 +2 +3	28 Ni Nickel 58.7 +2 +3	29 Cu Copper 63.5 +1 +2	30 Zn Zinc 65.4 +2	31 Ga Gallium 69.7 +3	32 Ge Germanium 72.6 +4 +2	33 As Arsenic 74.9 −3 +5	34 Se Selenium 79.0 −2 +4 +6	35 Br Bromine 79.9 −1	36 Kr Krypton 83.8
37 Rb Rubidium 85.5 +1	38 Sr Strontium 87.6 +2	39 Y Yttrium 88.9 +3	40 Zr Zirconium 91.2 +4	41 Nb Niobium 92.9 +5 +3	42 Mo Molybdenum 95.9 +6 +2	43 Tc Technetium (99) +7 +3	44 Ru Ruthenium 101.1 +3	45 Rh Rhodium 102.9 +3	46 Pd Palladium 106.4 +2 +3 +4	47 Ag Silver 107.9 +1	48 Cd Cadmium 112.4 +3	49 In Indium 114.8 +3 +1	50 Sn Tin 118.7 +2 +4	51 Sb Antimony 121.8 −3 +5	52 Te Tellurium 127.6 −2 +4 +6	53 I Iodine 126.9 −1	54 Xe Xenon 131.3
55 Cs Cesium 132.9 +1	56 Ba Barium 137.3 +2	57 La Lanthanum 138.9 +3	72 Hf Hafnium 178.5 +4	73 Ta Tantalum 180.9 +5	74 W Tungsten 183.9 +6 +2	75 Re Rhenium 186.2 +7 +3	76 Os Osmium 190.2 +2 +3 +4	77 Ir Iridium 192.2 +2 +3 +4	78 Pt Platinum 195.1 +2 +4	79 Au Gold 197.0 +1 +3	80 Hg Mercury 200.6 +1 +2	81 Tl Thallium 204.4 +1 +3	82 Pb Lead 207.2 +2 +4	83 Bi Bismuth 209.0 −3 +5	84 Po Polonium (209) ±2 +4	85 At Astatine (210) −1	86 Rn Radon (222)
87 Fr Francium (223)† +1	88 Ra Radium (226) +2	89 Ac Actinium (227) +3															

Other Metals (Al, Ga, In, Tl, Ge, Sn, Pb, Sb, Bi, Po)

Inner Transition Metals

Series														
LANTHANIDE SERIES	58 Ce Cerium 140.1 +3 +4	59 Pr Praseodymium 140.9 +3 +4	60 Nd Neodymium 144.2 +3	61 Pm Promethium (145) +3	62 Sm Samarium 150.4 +2 +3	63 Eu Europium 152.0 +2 +3	64 Gd Gadolinium 157.3 +3	65 Tb Terbium 158.9 +3 +4	66 Dy Dysprosium 162.5 +3	67 Ho Holmium 164.9 +3	68 Er Erbium 167.3 +3	69 Tm Thulium 168.9 −2 −3	70 Yb Ytterbium 173.0 −2 −3	71 Lu Lutetium 175.0 −3
ACTINIDE SERIES	90 Th Thorium 232.0 +4	91 Pa Protactinium (231) +4 +5	92 U Uranium 238.0 +3 +4 +5 +6	93 Np Neptunium (244) +3 +4 +5 +6	94 Pu Plutonium (244) +3 +4 +5 +6	95 Am Americium (243) +3 +4 +5 +6	96 Cm Curium (247) +3	97 Bk Berkelium (247) +3 +4	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)

†Masses in parentheses are the mass numbers of the most stable isotope.

Grade 10 Science (20F)

Practice Midterm Examination

Answer Key

Grade 10 Science

Practice Midterm Examination
Answer Key

Name: ______________________

Student Number: ______________________

Attending ❑ Non-Attending ❑

Phone Number: ______________________

Address: ______________________

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For Marker's Use Only

Date: ______________________

Final Mark ______ /100 = ________%

Comments:

Instructions

- You have a maximum of 2.5 hours to write this exam.
- Supplies required: pencil or pen, eraser, paper—you are permitted to bring a calculator, but it is not required
- This exam covers course material from Modules 1 and 2.
- This exam is worth 20 percent of your final mark.

Part A: Dynamics of Ecosystems

Section 1: Multiple Choice

Choose the best answer. Each question is worth one mark. This section of the midterm exam is worth 20 marks.

1. The relationship between a producer and a primary consumer is best illustrated by
   a. sheep eating grass
   b. wolves eating a moose
   c. mushrooms growing on rotting logs
   d. leaves growing on trees

DPSU-03-2014

2. Denitrification is defined as
   a. the conversion of nitrate and ammonia into plant proteins
   b. the cycling of nitrogen through an ecosystem
   c. the conversion of nitrate and ammonia into nitrogen gas
   d. the removal of nitrogen from the atmosphere

3. In a predator-prey relationship, an increase in the predator population is usually followed by
   a. an increase in the damage to the environment by the prey
   b. an decrease in the prey population
   c. an increase in the birth rate of the prey
   d. starvation of the prey

4. Which of the following is abiotic?
   a. water
   b. bacteria
   c. grass
   d. a skunk

5. A species is _________ when it is in danger of disappearing from the area in which it lives.
   a. extinct
   b. threatened
   c. endangered
   d. extirpated

6. The increase in the concentration of toxins along each level of a food chain is known as
   a. bioaccumulation
   b. biogeochemical
   c. biotoxification
   d. biocarcinogenics

Name: ____

7. A rabbit eats grass, and a fox eats the rabbit. In this food chain, the fox is a
   a. producer
   b. primary consumer
   c. secondary consumer
   d. scavenger

8. Which process does ***not*** directly affect the carbon cycle?
   a. ammonia levels in soil
   b. the eruption of a volcano
   c. algal blooms
   d. deforestation

9. Which statement is ***true*** for a pyramid of energy?
   a. Primary consumers contain the greatest amount of energy.
   b. The pyramid represents the total amount of living material per tropic level.
   c. The least amount of energy is within the producers.
   d. Less energy is available to organisms higher up the pyramid.

10. How do bacteria contribute to the nitrogen cycle?
    a. They are not involved in the nitrogen cycle.
    b. They allow primary consumers to use atmospheric nitrogen.
    c. They are responsible for nitrogen fixation.
    d. They absorb excess nitrogen gas from the atmosphere.

11. Which level of a food chain is at greatest risk due to the bioaccumulation of toxins?
    a. producers
    b. primary consumers
    c. secondary consumers
    d. tertiary consumers

12. Algal blooms are most likely to occur during
    a. spring
    b. summer
    c. autumn
    d. winter

13. A decomposer is
    a. an organism that eats plants
    b. a dead organism
    c. an organism that breaks down dead matter and waste
    d. an organism that lives inside a host organism and eats the host

14. The variety of organisms found within an ecosystem is known as its
    a. sustainability
    b. food web
    c. population dynamics
    d. biodiversity

15. Carrying capacity refers to
    a. the largest population of a species that a particular environment can support
    b. the greatest amount of biodiversity that a particular environment can support
    c. the largest size of predators that a particular environment can support
    d. the maximum number of plant species that a particular environment can support

16. If population growth is greater than zero, then the following is ***true***:
    a. There are more deaths and emigrants than there are births and immigrants in a population.
    b. The size of the population begins to decrease.
    c. There are more births and immigrants than there are deaths and emigrants in a population.
    d. The size of a population remains the same.

17. A tree produces acorns, and a squirrel eats the acorns. The squirrel dies and crows eat its dead body. In this food chain, the crows are defined as
    a. scavengers
    b. secondary consumers
    c. tertiary consumers
    d. decomposers

18. How did human use of DDT affect predatory birds such as the peregrine falcon?
    a. Falcons ingested the pesticide through their food.
    b. The pesticide caused the birds to lay eggs with thin, brittle shells.
    c. DDT affected the birds’ behaviour, causing them to abandon their nests.
    d. All of the above.

Name: ____

19. Which of these is ***not*** a producer?
    a. a tomato plant
    b. a pine tree
    c. a mushroom
    d. a dandelion

20. Why is the spread of zebra muscles a concern in Canada?
    a. The species has few natural predators in North America.
    b. They remove large quantities of plankton and algae from aquatic ecosystems.
    c. They are capable of reproducing in large numbers.
    d. All of the above.

Section 2: Explain

Answer the following questions in complete sentences. The mark allocations are provided for each question. This section of the midterm exam is worth 30 marks.

1. Describe the carbon cycle. You may use a diagram to help your explanation. (*3 marks*)

   In producers (plants, algae, etc.), carbon dioxide and water are converted into sugar (glucose) through the process of photosynthesis. Oxygen is given off.

   Plants use the glucose and oxygen to release energy through cellular respiration.

   Animals eat plants to get the sugars. They release the energy in the sugar by using oxygen and cellular respiration. Carbon dioxide and water are given off.

2. Hannah has studied a population of elk in northern Manitoba over the last decade, and she noticed that the herd has never grown over a hundred members. What factors may have limited the growth of this population? (*6 marks*)

   The population of the elk herd may have been affected due to density-dependent factors:

   - **Individuals may have** ***competed*** **for limited food and resources.**
   - **The population may have been cut down due to** ***predation*****.**
   - **The herd may have been afflicted by** ***disease*****.**
   - ***Stress*** **due to overcrowding may have caused death or, in females, miscarriage.**

   The elk could also have been affected by density-independent factors:

   - ***Natural occurrences*** **such as forest fires or heavy snowfall could have killed members.**
   - ***Human activities*** **such as hunting could have artificially stabilized the elk population.**

3. Kingsley is a farmer who grows canola. Recently, a salesperson has been visiting Kingsley's farm to advertise a new fertilizer spray made of pure nitrogen gas (N_2). By spraying his crops with this new gaseous fertilizer, the salesperson claims that Kingsley will be able to grow healthy crops in an environmentally responsible manner.

   a. Why do plants such as canola need nitrogen? (*1 mark*)

      Plants require nitrogen in order to produce proteins.

   b. Do you think this fertilizer is a good investment? Use your knowledge of the nitrogen cycle to explain your reasoning. (*3 marks*)

      - **The nitrogen gas fertilizer is a poor investment.**
      - **Plants do need nitrogen to produce proteins, but they are incapable of absorbing nitrogen directly from the air.**
      - **They can only take in nitrogen when it is in the form of nitrate and ammonia. A fertilizer made of nitrogen gas would be useless to Kingsley.**

      Students may also wish to add that nitrogen gas, when highly concentrated, is in fact deadly to plant life.

Name: ______________________________

4. Kingsley's neighbour, Elizabeth, grows corn. In previous years, Elizabeth has lost many of her crops due to worms. This season, Elizabeth sprays her crops with a brand-new pesticide to get rid of the worms. Over the summer, Elizabeth notices dozens of dead sparrows in her corn field, each body surrounded by buzzing flies.

   a. Identify the food chain in Elizabeth's corn field. Label each trophic level. (*4 marks*)

      Half mark for identifying each animal, half mark for identifying each animal's trophic level.

      Corn [producer] → Worms [primary consumer] → Sparrows [secondary consumer] → Fly [decomposer]

   b. Why are the sparrows dying? Suggest two reasons. (*4 marks*)

      - **The worms in Elizabeth's corn field may have been the primary food source of the sparrows. With most of the worms gone due to pesticides, the sparrows may have died off from hunger.**
      - **Alternately, the sparrows may have died by poisoning. By eating worms that ingested the pesticide, the birds may have accumulated a fatal level of toxins in their bodies.**

5. What is biodiversity, and how does it benefit an ecosystem? (*3 marks*)

   - **Biodiversity refers to the variety of species found within an ecosystem.**
   - **The biodiversity of an ecosystem is an indicator of its stability, health, and sustainability. Stable and healthy ecosystems will have a large number and variety of species present.**
   - **Sustainable ecosystems are renewable and continue without the addition of new materials.**

6. Use the table below to answer the following questions.

Year	Wolf Population	Deer Population
1991	20	4000
1992	24	4600
1993	33	5000
1994	44	4800
1995	56	4500
1996	48	4200
1997	42	3900
1998	36	3850
1999	38	3900
2000	38	3950

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a. How would you describe the relationship between the wolf population and the deer population? (*2 marks*)

- **The wolf and deer populations are highly interdependent.**
- **An increase in the deer population will lead to an increase in the wolf population. A decline in the deer population will lead to a decline in the wolf population.**

b. How did the deer population change between 1993 and 1997? What might have caused this change? (*4 marks*)

- **The deer population decreased every year between 1993 and 1997 (by over 1000 members).**
- **Because the wolf population increased during these years, the high number of wolves may have preyed upon the deer. An increase in the wolf population may have led to a decrease in the deer population because of increased predation.**
- **Additionally, harsh winters may have caused deer to starve.**
- **Additionally, a parasite or disease may have thinned out the herd.**

Name: ____

Part B: Chemistry

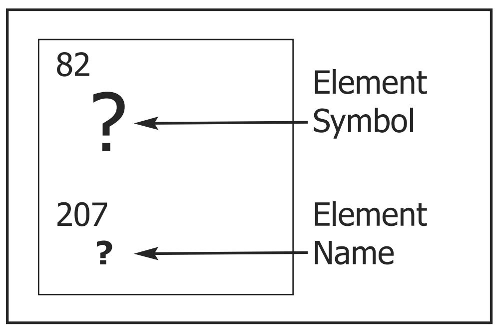
Section 1: Multiple Choice

Choose the best answer. Each question is worth one mark. This section of the midterm exam is worth 25 marks.

A copy of the Periodic Table of Elements is available at the end of this exam booklet.

1. An atom of barium has an atomic number of 56 and an atomic mass of 137u. What is the total number of protons and neutrons in one atom of barium?
   a. 56
   b. 81
   c. 137
   d. 193

2. The diagram below shows the atomic number and atomic mass of an element. Identify that element.
   a. Ga (gallium)
   b. Sb (antimony)
   c. Pb (lead)
   d. Po (polonium)



3. Sulphur is a member of which family?
   a. chalcogens
   b. halogens
   c. noble gases
   d. hydrogen

4. Which of the following ions would form a stable ionic compound with a single ion of iodide (I^-)?
   a. Na^+
   b. $Mg2^+$
   c. Cl^-
   d. Ar

5. What process takes place whenever a covalent bond is formed?
   a. proton transfer
   b. electron transfer
   c. proton sharing
   d. electron sharing

6. Which of the elements listed must bond with four atoms of hydrogen in order to fill its valence shell?
   a. B
   b. C
   c. N
   d. O

7. Which of the following compounds is an example of a diatomic molecule?
   a. H_3O
   b. NH_4
   c. Cl_2
   d. HBr

8. If calcium and oxygen were to form a stable ionic compound, which of the following chemical formulas would best represent that compound?
   a. CaO
   b. CaO_2
   c. Ca_2O
   d. CaO_3

Name: ____

9. An ionic bond forms when
   a. a noble gas combines with a halogen
   b. a metal combines with a non-metal
   c. an alkali metal gains an electron
   d. a chalcogen combines with hydrogen

10. Carbon and chlorine combine to form
   a. a covalent compound
   b. an ionic compound
   c. a strong acid
   d. carbon dichloride

11. Compound X is a newly discovered acid. Which statement best describes the properties of compound X?
   a. It feels slippery when touched.
   b. It reacts with many metals.
   c. It turns red litmus paper blue.
   d. All of the above.

12. Complete the following neutralization reaction:

$$\_\_\_\_\_\_ + NaOH \rightarrow Na_2CO_3 + H_2O$$

   a. $C(OH)_4$
   b. CH_2O_3
   c. $\mathbf{H_2CO_3}$
   d. CO_2

13. Which of the following chemical reactions is a single replacement reaction?
   a. $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$
   b. $\mathbf{Ca + AlCl_3 \rightarrow CaCl_2 + Al}$
   c. $NaBr + KI \rightarrow KBr + NaI$
   d. $Ca^{+2} + 2F^{-} \rightarrow CaF_2$

14. In the chemical reaction below, which compound is a salt?

$$HCl + Ca(OH)_2 \rightarrow H_2O + CaCl_2$$

   a. HCl
   b. $Ca(OH)_2$
   c. H_2O
   d. $CaCl_2$

15. What change is required to balance the following reaction?

$$Mg(OH)_2 + H_2S \rightarrow MgS + H_2O$$

   a. Double the amount of magnesium hydroxide reacted.
   b. Double the amount of hydrogen sulfide reacted.
   c. Double the amount of magnesium sulfide produced.
   d. Double the amount of dihydrogen monoxide produced.

16. What pH is considered neutral?
   a. 9.5
   b. 7.0
   c. 5.3
   d. 3.0

17. Pickles are cucumbers soaked in acetic acid. Acetic acid is best categorized as
   a. a strong base
   b. a weak base
   c. a weak acid
   d. a strong acid

18. What compound does the pancreas use to help neutralize fluid leaving the stomach?
   a. sulfuric acid
   b. sodium bicarbonate
   c. citric acid
   d. calcium hydroxide

Name: ____

19. What two groups of chemicals are responsible for the formation of acid rain?
    a. carbon monoxide and carbon dioxide
    b. chlorofluorocarbons and halons
    c. methane and gasoline
    d. sulfur oxides and nitrogen oxides

20. Which property of bases makes them useful as household cleaners?
    a. their ability to conduct electricity
    b. their ability to dissolve fats and proteins
    c. their ability to not react with metals
    d. their bitter taste

21. Which equation represents a neutralization reaction?
    a. $HCl + LiOH \rightarrow LiCl + H_2O$
    b. $Ca + S \rightarrow CaS$
    c. $CH_4 + O_2 \rightarrow CO_2 + H_2O$
    d. $4Cu + O_2 \rightarrow 2Cu_2O$

22. How does ozone contribute to human life on Earth?
    a. Ozone reduces the occurrence of acid rain.
    b. In the upper atmosphere, ozone filters harmful radiation from the Sun.
    c. Ozone breaks down harmful smog in the lower atmosphere.
    d. It is not useful at all and, in fact, causes lung damage in children.

23. What type of reaction is illustrated below?

$$2Hg + O_2 \rightarrow 2HgO$$

    a. synthesis reaction
    b. decomposition reaction
    c. combustion reaction
    d. single replacement reaction

24. The Montreal Protocol is an international agreement designed to
    a. ban the use of chlorofluorocarbons (CFCs)
    b. reduce industrial greenhouse gas emissions
    c. protect Canada's arctic wildlife
    d. eliminate the use of bisphenol-A in plastic products

25. How does a catalytic converter help reduce air pollution?
    a. A catalytic converter is used in post-combustion reduction of sulfur in industry.
    b. A catalytic converter is used to increase the efficiency of a car's combustion engine.
    c. A catalytic converter reduces nitrogen oxide emissions in vehicles.
    d. A catalytic converter is used to scrub impurities such as sulfur and ash from coal.

Section 2: Explain

Answer the following questions in complete sentences. The mark allocations are provided for each question. This section of the midterm exam is worth 25 marks.

1. List the four categories of clean coal technologies and briefly explain how they work. (*8 marks*)
    - ***Pre-combustion technologies*** **use chemical and biological technologies to clean the impurities from coal before it is burned.**
    - ***Combustion technologies*** **remove pollutants like sulfur from coal while it is burned.**
    - ***Post-combustion technologies*** **focus on removing sulfur compounds from the gases emitted from smokestacks and exhaust pipes.**
    - ***Conversion technologies*** **are used in automobiles to convert pollution emissions (such as carbon monoxide and nitrogen oxide) into less harmful gases (such as nitrogen gas and carbon dioxide).**

Name: ____

2. The combustion engine inside a car burns hydrocarbons in order to produce the mechanical energy that will move the vehicle. The skeleton chemical equation for the combustion of gasoline is written as follows:

$$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O + \text{energy}$$

If carbon dioxide and water are the only chemical products created in a car's combustion reaction, explain how cars are able to emit nitrogen oxides (such as NO and NO_2). (*2 marks*)

- **Although a combustion reaction does not utilize nitrogen, the atmosphere from which it obtains its oxygen gas (O_2) also contains nitrogen gas (N_2).**
- **Inside the heated engine of a car, some nitrogen gas and oxygen gas from the air will react with each other due to the high temperature and produce nitrogen oxides.**

3. Write a balanced chemical equation for the following reactions. Identify the type of reaction occurring.

a. Barium fluoride and lithium bromide react to produce barium bromide and lithium fluoride. (*2 marks*)

$BaF_2 + LiBr \rightarrow BaBr_2 + LiF$ (*skeleton equation—half mark*)
$BaF_2 + 2LiBr \rightarrow BaBr_2 + 2LiF$ (*balanced equation—full mark*)
This is a double replacement reaction.

b. The process of electrolysis splits water into hydrogen gas and oxygen gas. (*2 marks*)

$H_2O \rightarrow H_2 + O_2$ (*skeleton equation—half mark*)
$2H_2O \rightarrow 2H_2 + O_2$ (*balanced equation—full mark*)
This is a decomposition reaction.

c. Solid potassium and chlorine gas combine to form potassium chloride. (*2 marks*)

$K + Cl_2 \rightarrow KCl$ (*skeleton equation—half mark*)
$2K + Cl_2 \rightarrow 2KCl$ (*balanced equation—full mark*)
This is a synthesis reaction.

4. Write word equations for the following chemical reactions. (*6 marks, 2 marks each*)
   a. $Ba + O_2 \rightarrow BaO$
      Barium and oxygen gas combine to form barium oxide.
   b. $AlCl_3 \rightarrow Al + Cl_2$
      Aluminum chloride decomposes into aluminum and chlorine gas.
   c. $CH_4 + O_2 \rightarrow CO_2 + H_2O$
      Methane gas (or carbon tetrahydride) and oxygen gas react in a combustion reaction to produce carbon dioxide and water.

5. Acids and bases are commonly used in our homes, in industrial settings, and even in our bodies. Select specific acids or bases from the following list, and describe three ways that they may be used. You may describe three uses for one chemical, or a single use for three different chemicals. (*3 marks*)
   - sulfuric acid (H_2SO_4)
   - nitric acid (HNO_3)
   - hydrochloric acid (HCl)
   - sodium bicarbonate ($NaHCO_3$)
   - citric acid
   - ammonium hydroxide (NH_4OH)
   - sodium hydroxide (NaOH)
   - aluminum hydroxide ($Al[OH]_3$)

The student must describe three of the following:

Sulfuric Acid Uses

- **producing fertilizer**
- **washing impurities from gasoline**
- **cleaning metals such as iron and steel**
- **producing artificial clothing fabrics (rayon)**
- **powering automobile batteries**
- **producing detergents, dyes, pigments**

Nitric Acid Uses

- **producing fertilizer**
- **manufacturing explosives and rocket propellants**
- **manufacturing nylon**
- **dissolving metals**

Name: ____

Hydrochloric Acid Uses

- **found in the stomach—breaks down food**

Sodium Bicarbonate Uses

- **baking powder—used in food preparation**

Citric Acid Uses

- **found naturally in citrus fruits—used as food flavouring**

Ammonium Hydroxide Uses

- **window cleaners / household cleaners**

Sodium Hydroxide Uses

- **a.k.a. household lye—used as a drain cleaner**

Aluminum Hydroxide Uses

- **a.k.a. antacids—neutralizes hydrochloric acid in the digestive system to prevent heartburn**

Notes

The Periodic Table of the Elements

Key: Atomic number → 6; Symbol → C; Carbon; 12.0 ↑ Atomic mass*; +4 +2 } Combining capacity or Valence number

*Based on C^{12} = 12.00000

Group labels: 1 = Alkali Metals; 2 = Alkaline-Earth Metals; 3–12 = Transition Metals; 13–17 = Non-Metals (upper right) and Other Metals (lower right); 18 = Noble Gases

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 ±1 H Hydrogen 1.0																	2 He Helium 4.0
3 +1 Li Lithium 6.9	4 +2 Be Beryllium 9.0											5 +3 B Boron 10.8	6 +4 +2 C Carbon 12.0	7 −3 +5 N Nitrogen 14.0	8 −2 O Oxygen 16.0	9 −1 F Fluorine 19.0	10 Ne Neon 20.2
11 +1 Na Sodium 23.0	12 +2 Mg Magnesium 24.3											13 +3 Al Aluminum 27.0	14 +4 +2 Si Silicon 28.1	15 −3 P Phosphorus 31.0	16 −2 +4 +6 S Sulphur 32.1	17 −1 Cl Chlorine 35.5	18 Ar Argon 40.0
19 +1 K Potassium 39.1	20 +2 Ca Calcium 40.1	21 +3 Sc Scandium 45.0	22 +3 +4 Ti Titanium 47.9	23 +2 +5 V Vanadium 50.9	24 +2 +3 +6 Cr Chromium 52.0	25 +2 +7 Mn Manganese 54.9	26 +3 +2 Fe Iron 55.8	27 +2 +3 Co Cobalt 58.9	28 +2 +3 Ni Nickel 58.7	29 +1 +2 Cu Copper 63.5	30 +2 Zn Zinc 65.4	31 +3 Ga Gallium 69.7	32 +4 +2 Ge Germanium 72.6	33 −3 +5 As Arsenic 74.9	34 −2 +4 +6 Se Selenium 79.0	35 −1 Br Bromine 79.9	36 Kr Krypton 83.8
37 +1 Rb Rubidium 85.5	38 +2 Sr Strontium 87.6	39 +3 Y Yttrium 88.9	40 +4 Zr Zirconium 91.2	41 +5 +3 Nb Niobium 92.9	42 +6 +2 Mo Molybdenum 95.9	43 +7 +3 Tc Technetium (99)	44 +3 Ru Ruthenium 101.1	45 +3 Rh Rhodium 102.9	46 +2 +3 +4 Pd Palladium 106.4	47 +1 Ag Silver 107.9	48 +3 Cd Cadmium 112.4	49 +3 +1 In Indium 114.8	50 +2 +4 Sn Tin 118.7	51 −3 +5 Sb Antimony 121.8	52 −2 +4 +6 Te Tellurium 127.6	53 −1 I Iodine 126.9	54 Xe Xenon 131.3
55 +1 Cs Cesium 132.9	56 +2 Ba Barium 137.3	57 +3 La Lanthanum 138.9	72 +4 Hf Hafnium 178.5	73 +5 Ta Tantalum 180.9	74 +6 +2 W Tungsten 183.9	75 +7 +3 Re Rhenium 186.2	76 +2 +3 +4 Os Osmium 190.2	77 +2 +3 +4 Ir Iridium 192.2	78 +2 +4 Pt Platinum 195.1	79 +1 +3 Au Gold 197.0	80 +1 +2 Hg Mercury 200.6	81 +1 +3 Tl Thallium 204.4	82 +2 +4 Pb Lead 207.2	83 −3 +5 Bi Bismuth 209.0	84 ±2 +4 Po Polonium (209)	85 −1 At Astatine (210)	86 Rn Radon (222)
87 +1 Fr Francium (223)†	88 +2 Ra Radium (226)	89 +3 Ac Actinium (227)															

Inner Transition Metals

Series														
LANTHANIDE SERIES	58 +3 +4 Ce Cerium 140.1	59 +3 +4 Pr Praseodymium 140.9	60 +3 Nd Neodymium 144.2	61 +3 Pm Promethium (145)	62 +2 +3 Sm Samarium 150.4	63 +2 +3 Eu Europium 152.0	64 +3 Gd Gadolinium 157.3	65 +3 +4 Tb Terbium 158.9	66 +3 Dy Dysprosium 162.5	67 +3 Ho Holmium 164.9	68 +3 Er Erbium 167.3	69 −2 −3 Tm Thulium 168.9	70 −2 −3 Yb Ytterbium 173.0	71 −3 Lu Lutetium 175.0
ACTINIDE SERIES	90 +4 Th Thorium 232.0	91 +4 +5 Pa Protactinium (231)	92 +3 +4 +5 +6 U Uranium 238.0	93 +3 +4 +5 +6 Np Neptunium (244)	94 +3 +4 +5 +6 Pu Plutonium (244)	95 +3 +4 +5 +6 Am Americium (243)	96 +3 Cm Curium (247)	97 +3 +4 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)

†Masses in parentheses are the mass numbers of the most stable isotope.

Videos that may be used in the next unit:

https://youtube.com/playlist?list=PLw1g3n2IMV7MMieBe6dyubk_fWcrPuNgq

Grade 10 Science (20F)

Module 3

In Motion

This module contains the following:

Module 3: Introduction

Welcome to Module 3: In Motion. In this module, you will learn about the physics of objects in motion, especially as they apply to motor vehicles.

This module is very important because you will learn things that will help you become a better driver and that will lessen your chances of causing a serious car accident.

Learning Activities

There are several learning activities placed throughout this module, which will help you to practise using the information you will learn. The answer keys for each of these learning activities are found in Module 3 Learning Activity Answer Key. Check the answer key carefully and make corrections to your work.

Assignments

When you have completed the assignments for Module 3, submit your completed 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.

Assessment Checklist

- ❏ Lesson 8 — Assignment 3.1: Inertia and the Unrestrained Passenger
- ❏ Lesson 10 — Assignment 3.2: The Link between Force and Motion
- ❏ Lesson 17 — Assignment 3.3: Speed and Braking Distance

These assignments will be worth a portion of the 60 percent of the total marks you will receive for assignments in this course.

What Will You Need?

Required Electronic Resources

For this module, you will need the following electronic resources.

- **Videos:** You will need to view the Grade 10 Science videos, which are available in the learning management system (LMS). If you do not have access to the Internet, or if you need a copy of the videos, contact the Distance Learning Unit at 1-800-465-9915.
- **Booklet:** In order to complete this module, you will need access to the booklet *In Motion: A Learning Resource for Students,* which is found in the learning management system (LMS). If you do not have access to the Internet, contact the Distance Learing Unit at 1-800-465-9915 to obtain a copy of the *In Motion: A Learning Resource for Students* booklet.
- **A computer/mobile device** to view video and PDF files.

Optional Resources

- a **calculator** to help you complete your learning activities and assignments
- access to the following equipment, to perform the optional Learning Activity 3.7
  - small toy car
  - metric ruler
  - protractor
  - long, flexible material for a ramp
  - support pillars x 2, such as a stack of books
- access to the following equipment, to perform the optional Learning Activity 3.10
  - marble or ball bearing
  - long, flexible material for a ramp
  - support pillars x 2, such as a stack of books

- access to the following equipment, to perform the laboratory option of Assignment 3.1 (You may also choose to complete this assignment by viewing the *Grade 10 Science Inertia and the Unrestrained Passenger* video.)
  — small toy car
  — long, flexible material for a ramp
  — support pillars x 2, such as a stack of books
  — barrier, such as a book
  — metric ruler
  — stopwatch
  — modelling clay to make a toy passenger for the toy car

- access to the following equipment to perform the laboratory option of Assignment 3.3 (You may also choose to complete this assignment by viewing the *Grade 10 Science Speed and Braking Distance* video.)
  — an inclined plane (a long, flat surface that can be raised on an angle)
  — a piece of paper (10 cm x 12 cm)
  — metric ruler
  — toy car
  — masking tape

Notes

Lesson 1: Position and Displacement

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe the relationship between position and displacement
- ❑ identify the position of origin for an object in motion
- ❑ recognize displacement as being either positive or negative
- ❑ calculate Δd (change in position)

Key Words

- displacement
- position
- origin
- Greek letter *delta* (Δ)
- motion

Introduction

You are driving to a babysitting appointment one afternoon, but you get lost on the way and now you are late. If you call home for directions, how can you describe where you are? How can you determine how far you have travelled away from home and from where you really want to be? This lesson will show you how movement is recorded, and how you can keep track of your travels.

Describing Movement in Physics

What does it mean to move? First, consider the opposite: if you stay in one place without changing your position, you would be standing still. In order to move, you must change your **position**—the place where you are located. Consider these examples of movement between positions:

"I got out of bed and went to the kitchen."

"Carrie walked five blocks from Main Street to arrive at the grocery."

"Lorry lives in Gladstone and drove 150 kilometres to visit Winnipeg."

Notice that each example describes a starting point (bed, Main Street, Gladstone) as well as an ending point (kitchen, grocery, Winnipeg). In order to describe movement, you must choose a position from which you will take measurements. This reference point is called the **origin**.

Once you decide on an origin and come to your end point, you can calculate your displacement. **Displacement** is the change in position between an origin and end point. In Lorry's example, her origin was the town of Gladstone, and her ending point was Winnipeg. By moving from one point to the other, she experienced a displacement of 150 kilometres. Put another way, at the end of her travels she was 150 kilometres away from where she started.

Displacement is represented by the symbol $\boldsymbol{\Delta d}$. The Greek symbol Delta ($\boldsymbol{\Delta}$) stands for "change in" while the letter d refers to position.

Displacement = final position – initial position

$\Delta\vec{d} = \vec{d}_2 - \vec{d}_1$

Lorry's Displacement = Winnipeg's Position – Gladstone's Position

Lorry's Displacement = 150 km East – 0 km

Lorry's Displacement = 150 km East

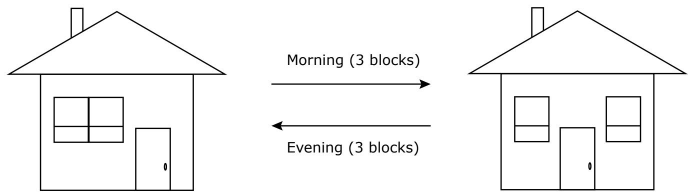
Since Lorry had to travel eastward to reach Winnipeg, her displacement is specified as 150 kilometres **to the east**. When working with displacement you must always list the direction of motion. The next example will demonstrate why this is essential.

As soon as you include a direction, you must use a vector notation ($\vec{\ }$). Any measure that includes both a quantity or size (in units) and a direction is called a **vector quantity**. Displacement is a vector quantity. In the example above, Lorry's displacement or $\Delta\vec{d}$ was 150 kilometres east.

Distance versus Displacement

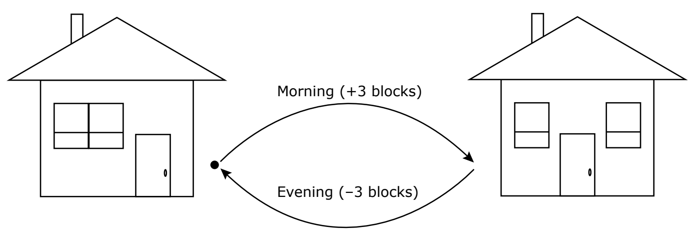
Say you want to visit a friend who lives three blocks away from your home. You wake up, walk to your friend's house, spend the day together and then walk back home in the evening. Consider the following:

- At the end of the day, how far of a distance did you walk?
- At the end of the day, how far did you displace yourself from your home?



If your friend lives three blocks away, then to visit his house and return to your own, you would have travelled a total **distance** of six blocks.

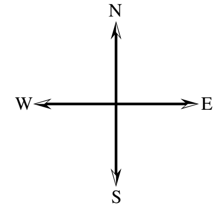
Since your final and initial positions are one and the same, at the end of the day you had a total **displacement** of 0 blocks from your home. You returned to the point from where you began.



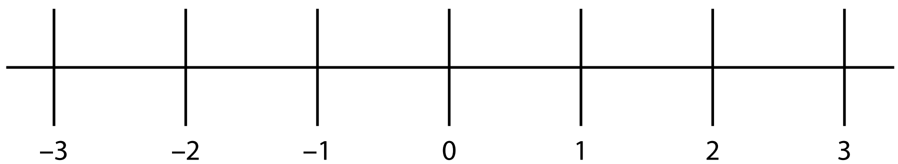
It is important to keep in mind the difference between *distance* and *displacement*.

- Distance refers to the **total movement** in all directions.
- Displacement refers to the **net movement** from an origin. Moving farther and then returning closer to an origin results in a smaller net movement.

There are several systems used to measure displacement. In geography, the Cartesian coordinates of **north**, **south**, **east**, and **west** are used to compare displacement. More generally, you can refer to displacement as moving **left**, **right**, **up**, **down**, **forward**, or **backward**.



On a number line (such as the one below) where each number represents a unit of distance, displacement is referred to as **positive** or **negative**. Moving to the right of the line results in positive displacement (+) while moving left results in negative displacement (–).



Learning Activity 3.1: Distance and Displacement

1. The following data represents the initial (d_1) and final (d_2) positions of a car, bicycle, pedestrian, and skateboarder. All positions are measured with reference to origin point "0."

	Car	Bicycle	Pedestrian	Skateboarder
$\vec{d}_1$	+2	+7	–1	+4
$\vec{d}_2$	+14	+2	+2	–1

   a. Draw a number line and label an origin as point "0." Mark the initial position of each object above the line.
   b. Mark the final position of each object below the line.
   c. Calculate the displacement of each object.
   d. Assuming that each displacement takes place in the same period of time, describe the motion of each vehicle and pedestrian. In what direction are they travelling, and how far? Which is moving the fastest? Which is the slowest?

2. Two taxis are travelling along Pembina Highway in opposite directions. Taxi A changes its position from +6 to +10 during the same time as Taxi B moves from +6 to +1.

   a. Draw a diagram to show the initial and final positions of each taxi.
   b. Calculate the displacements of each taxi.

c. Describe the movement and speed of both taxis. Which vehicle is moving faster?

3. A truck driver travelling on the Trans-Canada highway gets a flat tire and radios for help. She reports her current position as on the Trans-Canada highway 7 km from Brandon.
   a. What information is missing from the driver's report?
   b. A roadside assistance vehicle is currently located 10 km east of Brandon (+10 km). Use a number line to determine how far the vehicle would need to travel in order to reach the truck (at all possible positions).
4. Jack is searching for a buried treasure. From his current position, his map tells him to move 10.0 km north through an alligator-infested swamp, 5.0 km east through a scorching-hot desert, and then 10.0 km south through a field of poison oak.
   a. Draw a diagram of the route Jack must take according to the map. Label all distances.
   b. What is the total distance Jack must travel according to these directions?
   c. How far will Jack displace himself from his initial position after following the map's directions?
   d. What would be the easiest way for Jack to reach the treasure?
5. How are distance and displacement similar? How are they different?

Check the Learning Activity Answer Key found at the end of this module.

Summary

Displacement is your net movement between an origin to an end point, while distance is the total movement that took place. Sometimes, the distance you travel is greater than your displacement—you might overshoot your destination and have to backtrack. Displacement is only concerned with the shortest route between two points. Now that you've covered how to track motion, next you'll find out about how time is recorded.

Notes

Lesson 2: Measuring Time, Scalars, and Vectors

Lesson Focus

After completing this lesson, you will be able to

- ❑ differentiate between an instant and an interval of time
- ❑ calculate an interval, given the appropriate data
- ❑ give examples of intervals and instants
- ❑ work with both vector and scalar quantities

Key Words

- instant
- interval
- scalar
- vector

Introduction

Think of all the quantities you are able to count and measure—the time it takes to walk to school; the temperature outside on a hot day; the height of a tree in the park. In physics, these are referred to as **scalar quantities**—quantities possessing a size or magnitude that can be measured.

Here, you will review scalar quantities and how they differ from the category of vector quantities. You will also examine the specific scalar quantity of time, and how it is measured.

Measuring Time

There are two ways we can measure time: as an instant or as an interval. An **instant** of time is a reading at a particular, precise moment. For example, leaving for school at exactly 8:15 a.m. represents an *instant* of time. If, on the other hand, you measure the time it takes for you to walk from home to school, that would represent an *interval* of time. An **instant of time** relates to a precise moment, while an **interval of time** relates to the difference between two instants.

Intervals of time are represented by the symbol $\boldsymbol{\Delta t}$. The Greek symbol Delta (Δ) stands for "change in" while the letter t refers to time.

Interval of Time = Final Instant – Initial Instant

$$\Delta t = t_2 - t_1$$

To illustrate, if you left for school at 8:15, and arrived at school at 8:30, you would have walked for an interval of fifteen minutes.

$$\Delta t = t_2 - t_1$$
$$\Delta t = 8{:}30 - 8{:}15$$
$$\Delta t = 15 \text{ minutes}$$

Learning Activity 3.2: Time Management

1. When would it be useful to track time in intervals, and when would you need to track an instant of time? Provide an example of each.
2. Identify from the following list examples that are intervals of time and those that are instants of time.
    a. A flight from Winnipeg to Toronto takes 1 hour and 51 minutes.
    b. The train arrives at 1:13 p.m.
    c. The next bus should come at 8:20 a.m.
    d. A phone conversation begins at 7:00 p.m. and ends 20 minutes later.

Check the Learning Activity Answer Key found at the end of this module.

Scalars versus Vectors

When measuring quantities in science, it is sometimes necessary to state the direction in which some quantities act. Most quantities we measure are scalars. **Scalars** are measured with a size or magnitude but without regard to direction. For example, temperature is a scalar. While it can be positive or negative, it does not have a direction like right/left or east/west associated with it. Time is another example of a scalar quantity. The symbol for an interval of time is Δt. Instants of time are indicated by t_1, t_2, et cetera. Mass (m) and length (l) are also scalar quantities.

Vectors are quantities with magnitude *and* direction. Force ($\vec{F}$) is a vector. You can pull on a door handle with a force of 25 newtons (25 N) or you can push against it with a force of 25 newtons. While these forces have the same magnitude, they act in different directions. Once force will open the door, the other will not.

Displacement ($\Delta\vec{d}$) is also a vector quantity. Depending on the direction of your displacement, you can end up in vastly different locations.

Speed versus Velocity

In the study of motion, the quantities of speed and velocity are often confused. **Speed** (Δv) describes how fast an object is moving, regardless of direction. The speedometer of a car measures speed. It indicates how fast the car is moving, but does not include the direction. For example, 100 km/h is the legal speed for a car on the highway.

Velocity ($\Delta\vec{v}$), though, is a **vector quantity**. If we start at a point and travel at 100 km/h east for one hour, we will end up 100 km east of our starting point. If we travel at 100 km/h west, starting from the same point, we will end up 100 km west of the starting point. These two velocities, 100 km/h east and 100 km/h west, are definitely different velocities. It is the direction that makes them different.

Learning Activity 3.3: Scalar or Vector?

1. Explain the difference between a scalar quantity and a vector quantity.
2. For each quantity, give the symbol and unit and state whether it is a vector or scalar quantity.

Quantity	Symbol of the Quantity	Unit	Vector or Scalar
time instant			
time interval			
distance travelled			
displacement			
mass			
length			
speed			
velocity			
force			

Check the Learning Activity Answer Key found at the end of this module.

Summary

Scalars are quantities with size or magnitude only. We give the value of such a quantity with a number for its size and a unit to tell us the type of quantity. A **vector is a quantity with both magnitude and direction**. We give the value of a vector using a number for its size, a unit to tell us the type of quantity, and a direction. The scalar quantity of time is measured either as an instant or an interval.

Lesson 3: Displacement, Time, and Velocity

Lesson Focus

After completing this lesson, you will be able to

- ❑ define uniform motion
- ❑ analyze the visual relationship among displacement, time, and velocity for an object in uniform motion (what you would be able to see)
- ❑ analyze the numerical relationship among displacement, time, and velocity for an object in uniform motion
- ❑ calculate velocity, given displacement and time
- ❑ solve problems involving displacement, time, and velocity for an object in uniform motion

Key Words

- velocity
- uniform motion
- speed
- position-time graph

Introduction

So many people are concerned with moving quickly—athletes, workers, drivers—the list goes on. Whether you are planning a trip and want to know how long until you arrive, or whether you would like to avoid getting a ticket for speeding in your car, it is handy to know how to keep track of speed and velocity. This lesson with show you the basics about velocity.

Measuring Velocity

If you are faster than others, then you are able to finish a task or arrive at a destination in a shorter amount of time. Think about how a race works: every participant must travel the same distance, but the runner who crosses that distance in the shortest interval of time is considered the fastest.

Speed is determined by the distance you travel during an interval of time. Think back to the speedometer in a car and the units it uses to track movement: kilometres-per-hour; miles-per-hour. The needle on the speedometer tells you that "every hour, you will travel *X* kilometres." The higher the number it points to, the greater the distance you will travel during one hour.

Velocity is a vector quantity that is used when referring to speed. Simply put, **velocity** is a certain speed in a stated direction. In order to calculate velocity, you need two pieces of information: the change in position and the change in time. The equation for velocity looks like this:

Average Velocity = change in position/change in time

or

Average Velocity = displacement/time interval

Remember that "change" can also be represented by the symbol delta (Δ). Therefore, you could also write the equation for velocity as:

$$\vec{v}_{avg} = \Delta\vec{d} \,/\, \Delta t$$

Uniform Motion

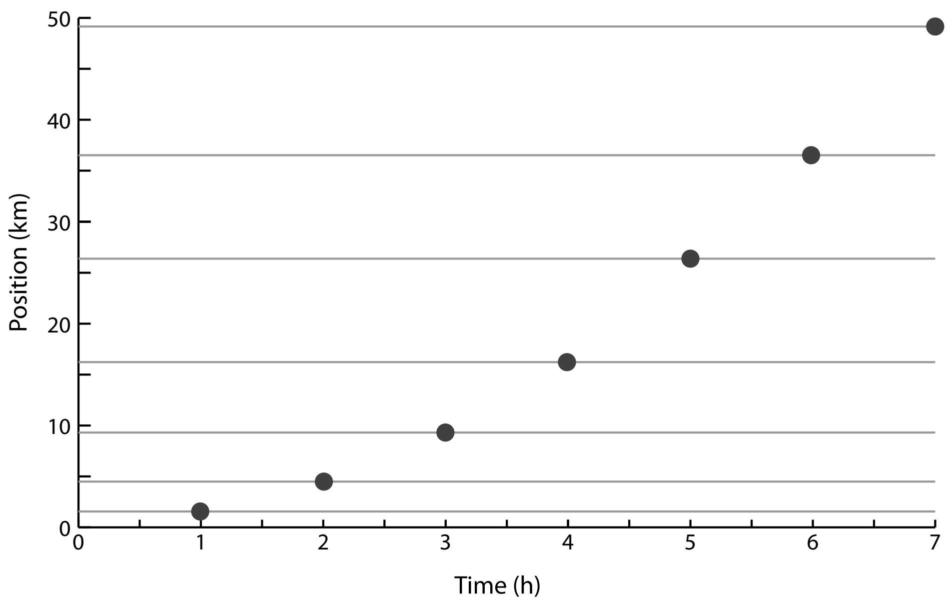
As long as an object continues to move in the same direction at the same speed, its motion is constant. You can also say its motion is **uniform**.

You may notice that the symbol for velocity includes a subscript—*avg*, or "average." This is because the velocity equation assumes an object is travelling at uniform motion. As you can imagine, it is easy for objects to change their velocity. Cars change velocity every time the driver presses down on the gas or brake pedal. The next lesson will discuss scenarios where velocity is changing but for now you will focus on moments of uniform motion.

Measuring Position and Time on a Graph

It would be useful to have a method for illustrating how an object's position changes over time. This would provide a quick way to observe patterns of movement, or to monitor the velocity of an object.

One effective illustration is a **position-time graph**. You are probably familiar with constructing graphs from your studies in mathematics. On a position-time graph, time is monitored on the horizontal X-axis while position is tracked on the vertical Y-axis.

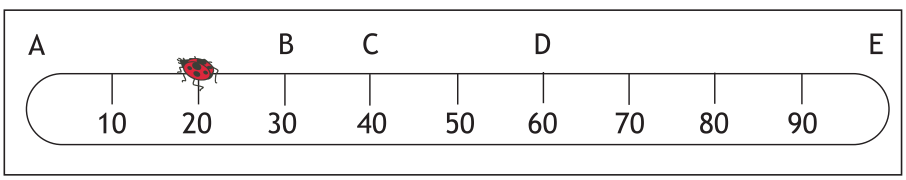


Once you place your coordinates on the position-time graph, you can join them with a line. The shape of the line on a position-time graph—be it straight, curved or horizontal—can tell you a lot about the velocity of the object being monitored. You'll learn more about reading graphs in future lessons.

Learning Activity 3.4: Velocity of an Object in Motion

1. For each set of variables, find the missing information and fill in the blank spaces in the table. Use a "+" sign to indicate forward movement and a "–" sign to indicate backward movement.

Velocity of an Object in Motion		
Change in Position (cm)	**Change in Time (s)**	**Velocity (cm/s)**
–20 cm	5 s	
	13 s	+52 cm/s
+50 cm		+5 cm/s
–120 cm	10 s	
	75 s	–3 cm/s



2. A somewhat confused ladybug is moving back and forth along a metre stick. Determine both the displacement and distance travelled by the ladybug as it moves between the following points:

   a. A to B

   b. C to B

   c. C to D

   d. C to E and then to D

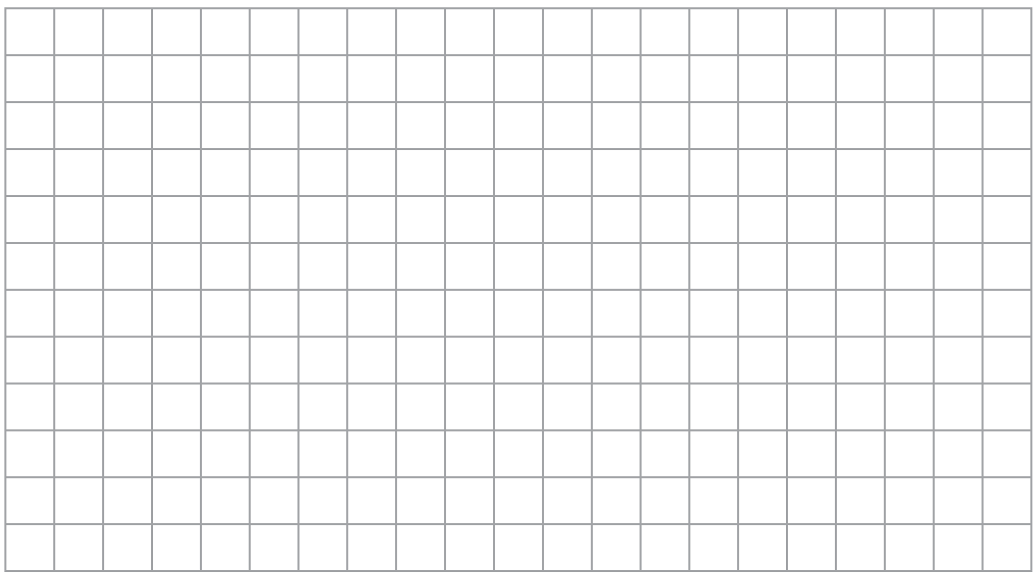
   e. In the diagram above, **east** points to the **right**. During which of the intervals in #1 is the ladybug moving in the **easterly** direction? In the **westerly** direction?

continued

Learning Activity 3.4 (continued)

3. Below is a table showing the position above the ground floor of an elevator at various times. On the graph below the table, plot a graph of position-time.

Time (seconds)	0	4	20	32	36	60	72
Position above the ground floor (metres)	4.0	8.0	8.0	16	20	20	12



4. A worried student is waiting to see the principal. He paces back and forth in the hallway in front of the principal's office. The hallway runs north and south. The door to the office is the origin, 0 m. Here is a description of the student's motion.

   The student starts at 5.0 m N of the office door. He walks to the south for 7.0 m during 10.0 s. He stands still for 5.0 s. He turns around and walks 15.0 m N during 15.0 s. He stops to say "Hello" to a friend and remains still for 10.0 s. Finally, the principal calls him to the office door. It takes the student 10.0 s to reach the door.

   a. What is the total time the student spent in the hallway?

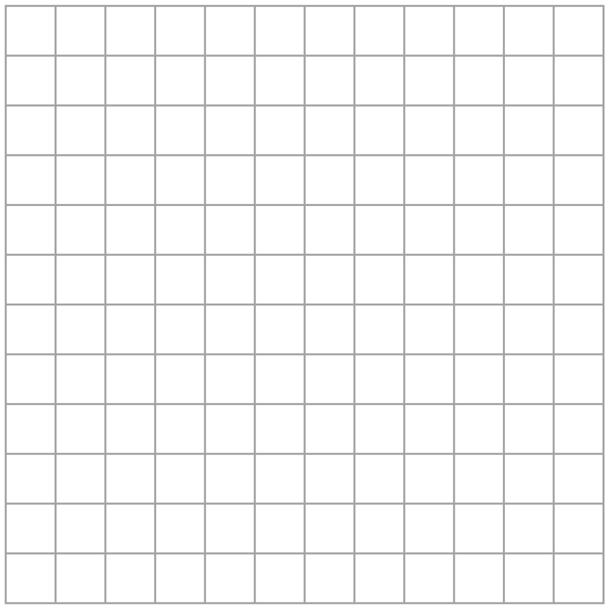
   b. What was the distance travelled by the student during his pacing?

   c. What was the average speed of the student during his pacing?

continued

Learning Activity 3.4 (continued)

d. On the graph below, plot time on the horizontal axis and position on the vertical axis. Use straight-line segments to join the points of position-time that you plot.



e. What is the total displacement for the student’s journey? Find this from the graph.

f. What is the average velocity for the whole journey?

5. Briefly explain the terms *speed*, *velocity*, and *uniform motion*. How are they related to one another?

Check the Learning Activity Answer Key found at the end of this module.

Summary

It is important to emphasize the difference between speed and velocity. Speed measures your total distance over time, while velocity measures your total displacement over time. Drawing a position-time graph provides you with a straightforward way to track displacement over time. The next lesson will show you another use for these graphs: finding velocity.

Lesson 4: Graphing Velocity

Lesson Focus

After completing this lesson, you will be able to

- ❑ analyze the graphical relationship among displacement, time, and velocity for an object in uniform motion
- ❑ use a position-time graph to determine velocity

Key Words

- slope (rise/run)
- speed
- velocity
- constant
- steepness
- Δd
- Δt

Introduction

Up to this point, you have studied velocity as a definition and as a mathematical equation. However, there are more ways we can communicate this information, such as by constructing a graph. Knowing and understanding more ways to communicate the same information better helps us understand the concepts of motion. In this lesson, you will learn how to graph data and understand what the graph tells you about the motion of the object.

Graph Recap

As you already know, there are two axes on a graph: the *x* and *y* axes. The slope of a line (or the steepness) indicates the rate of change of the variable on the *y*-axis compared to the variable on the *x*-axis. We can calculate the slope of a graph by using the following relation:

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}} = \frac{\Delta y}{\Delta x}$$

The change in the Y-axis is called the **rise** of the graph. The change in the X-axis is called the **run** of the graph. This means that on a position-time graph, the slope formula could be expressed as

$$\text{Slope} = \frac{\Delta \vec{d}}{\Delta t}$$

Doesn't this equation seem familiar?

Slopes of Position-Time (P-T) Graphs for Uniform Motion

The **slope** of a P-T graph gives us the **velocity** of the object:

$$\vec{v}_{\text{average}} = \frac{\Delta \vec{d}}{\Delta t} = \text{slope}$$

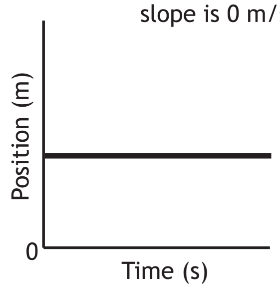
Remember that slope refers to the steepness of a line. Therefore, the steeper the line on a P-T graph, the greater the velocity will be for that time interval or instant in time. Since velocity is a **vector** quantity, it is important that the direction of the velocity is always included. Remember: velocity is **speed with direction**.

This would be a good time to review pages 12 to 14 of the *In Motion* booklet.

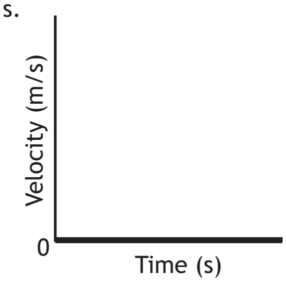
Here are some examples of P-T graphs with various slopes. All the time intervals are equal for the time between the positions of the car.

Example 1: No Movement

This graph indicates the object stayed at the same position or did not move. The slope is 0 m/s. The velocity is 0 m/s.

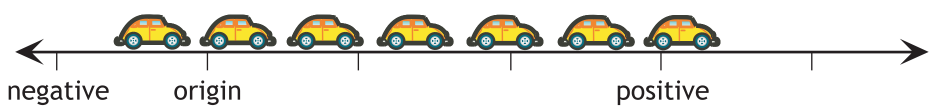


Position-Time Graph

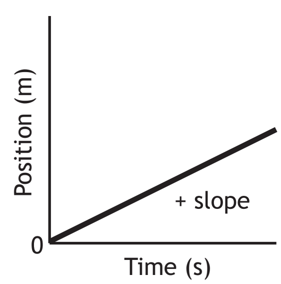


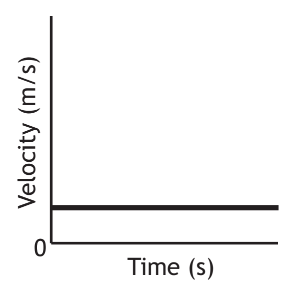
Velocity-Time Graph

Example 2: Slow Uniform Motion in the Positive Direction



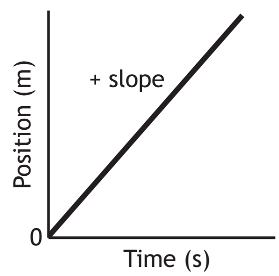
This car is moving away from the origin in the positive direction at a constant speed. Since the speed and direction remain the same, the velocity-time graph records a horizontal line.

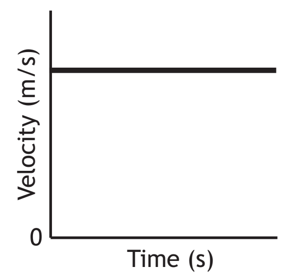




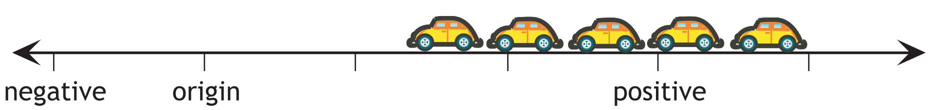
Example 3: Rapid Uniform Motion in the Positive Direction

Because this car is moving at a faster speed, the position-time graph displays a much steeper slope. The velocity-time graph records a much higher value, but because movement remains uniform, the graph remains horizontal.

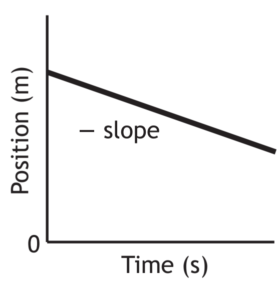


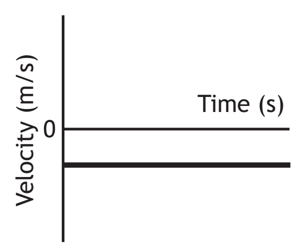


Example 4: Slow Uniform Motion in the Negative Direction

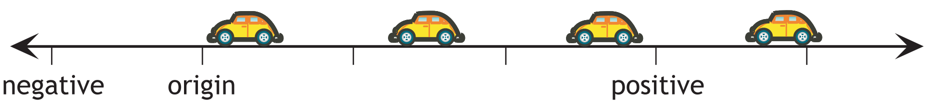


This automobile is heading towards the origin, travelling in the negative direction. Speed is still constant and so the velocity-time graph records a horizontal line. Notice though, that it is in the negative quadrant of the graph. On a velocity-time graph, the direction of motion (positive/negative, right/left) is indicated by the position of the line in relation to the X-axis. Motion in the "negative" direction is recorded below the X-axis. Motion in the "positive" direction is recorded above the X-axis.

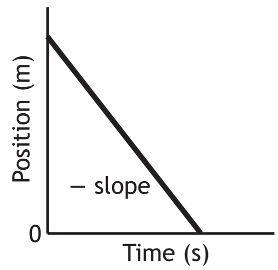


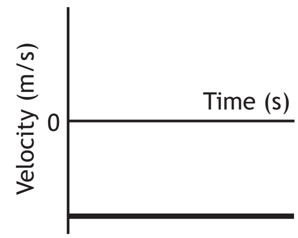


Example 5: Rapid Uniform Motion in the Negative Direction

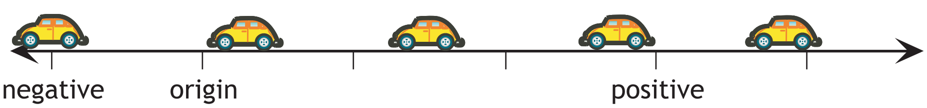


This car is also moving in the negative direction. Because its velocity is much faster than the car in Example 4, the velocity-time graph records a horizontal line much lower down on the Y-axis. Remember: travelling at –20 m/s is still faster than –10 m/s. The negative symbol indicates the direction of motion while the number indicates the actual speed.

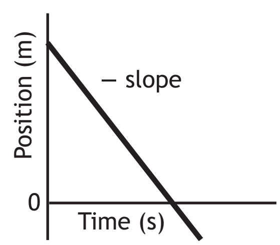


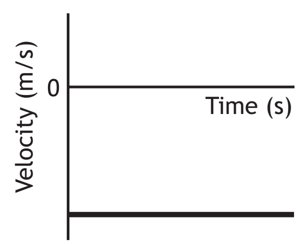


Example 6: Rapid Uniform Motion in the Negative Direction, Part 2



These final graphs are a continuation from Example 5, showing the car's position and velocity after passing the origin. Since velocity did not change between Examples 5 and 6, the velocity-time graph remains identical.





Learning Activity 3.5: Velocity on a Graph

1. For each of the following cases, sketch a diagram that shows initial position, final position, the direction of motion, and the elapsed time. Use this diagram to calculate the average velocity of the object.
   a. A bicycle travels 36 km in 1.2 hours.
   b. A person runs 17 m toward a bus stop in 2 seconds.
   c. A car passes 6 telephone poles, each spaced 50 m apart, in 18 seconds.
   d. A toy car moves along a track from +2 cm to +26 cm in 0.5 seconds.
2. For each example in Question 1, comment from your personal experience whether the object is moving slowly, at an average speed, or quickly, or if it has an unrealistic velocity.
3. A skateboarder is coasting at a velocity of 2 m/s away from an intersection. If we let the intersection be the origin, how far will the boarder travel in 3.5 seconds?
4. A toy car rolls off a ramp and onto a horizontal track with a uniform motion of 1.5 m/s. The end of the ramp is at position –12 cm. If the car reaches the end of the track in 0.4 seconds, what was the length of the track? Include a diagram and label the origin.

Diagram A

Diagram B

5. The above pictures were taken by a high-speed camera set up along the highway. Each car was photographed five times at one-second intervals. The five photos were then pasted together to produce the final diagrams.

continued

Learning Activity 3.5 (continued)

a. Use a metric ruler to measure the distance travelled by the car between each interval. Record your results in Tables A and B. Use the back of the first car as your origin (0 seconds) and measure to the nearest 0.1 centimetres.

Table A	
Position (cm)	Time (s)
	0
	1
	2
	3
	4

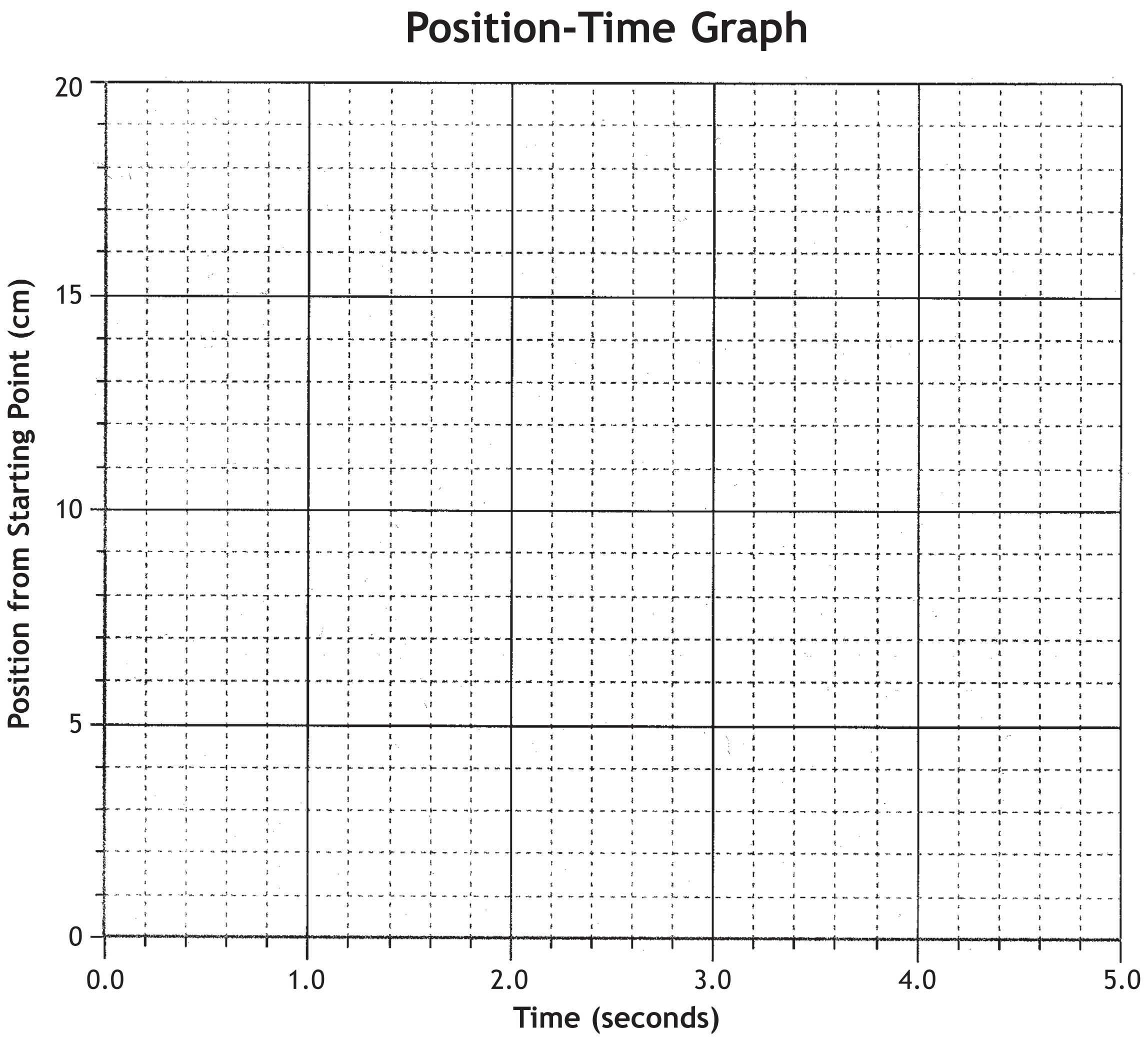
Table B	
Position (cm)	Time (s)
	0
	1
	2
	3
	4

b. Graph the data in Tables A and B on the position-time graph.

c. Calculate the average velocity for Cars A and B.

continued

Learning Activity 3.5 (continued)



Check the Learning Activity Answer Key found at the end of this module.

Summary

Our first example of using this type of graph is one where position is plotted against time (position versus time). As you already know, velocity is the change in position divided by the change in time. Therefore, we can determine velocity from this type of a graph.

Lesson 5: Velocity, Time, and Accelerated Motion

Lesson Focus

After completing this lesson, you will be able to

- ❑ construct a velocity-time graph
- ❑ interpret a velocity-time graph to describe uniform or non-uniform motion

Key Words

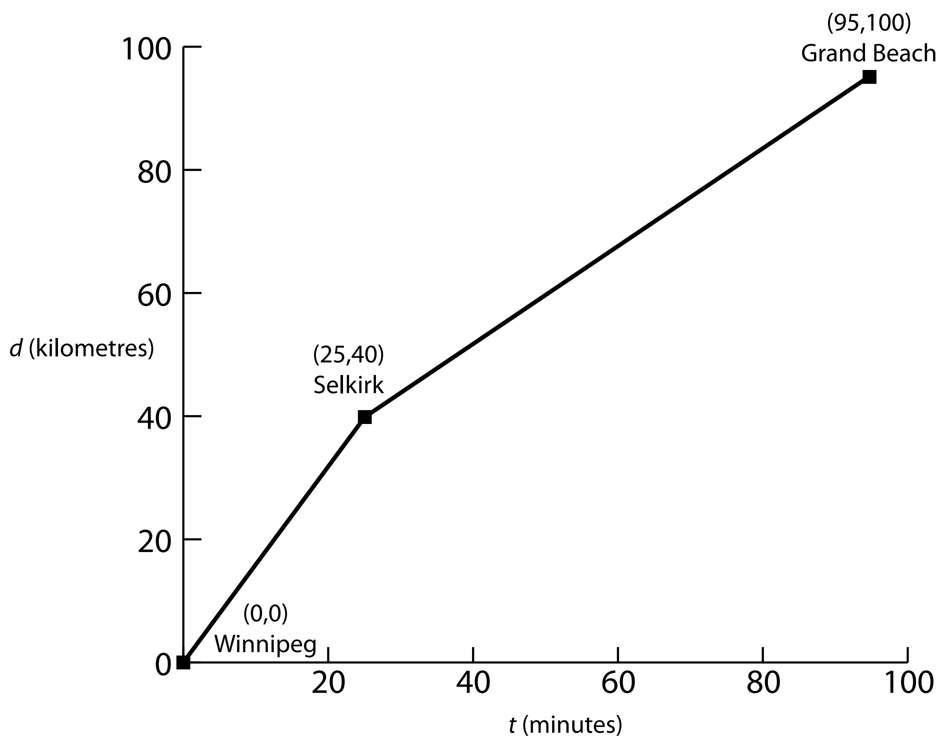
- accelerated motion
- uniform motion
- average velocity
- instantaneous velocity
- acceleration
- velocity-time graph

Introduction

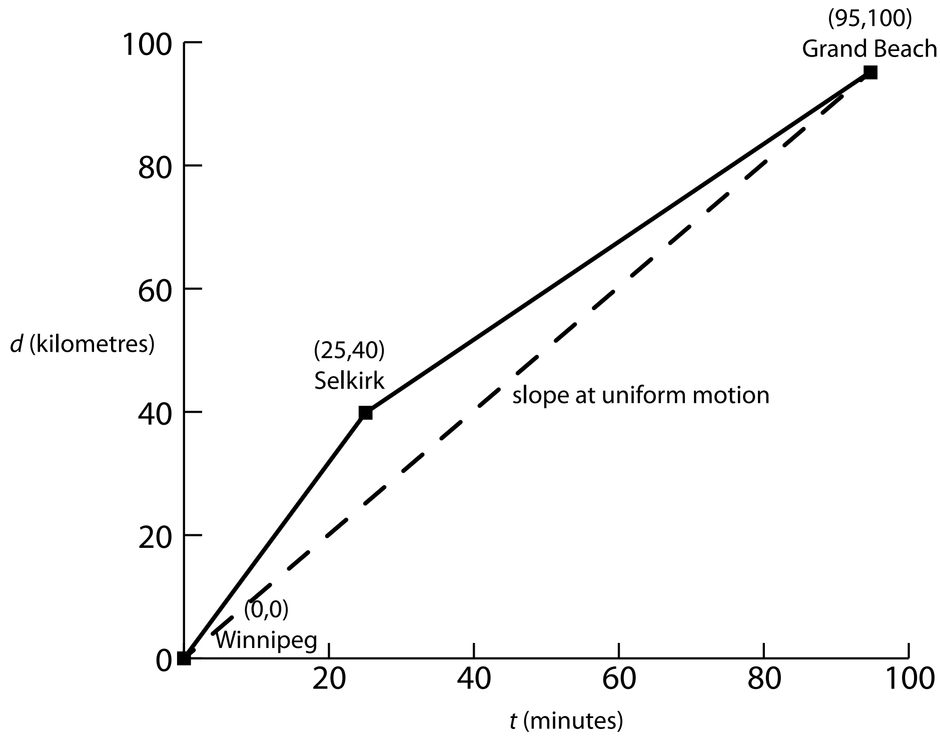
It is quite rare that an object moves in uniform motion for any length of time. Think about riding your bicycle at what you consider to be a constant speed. Every time you turn a corner or go over a speed bump you are speeding up or slowing down, even if only slightly. This means that you are accelerating, which automatically means you are no longer using uniform motion. In this lesson you will analyze objects that change their velocity, and learn how to track accelerated motion.

Understanding Average Velocity

The equation for velocity you have used so far ($\vec{v}_{avg} = \Delta\vec{d} / \Delta t$) measures an object's **average velocity**—the **displacement** during an interval of time. You should remember from earlier lessons that displacement does not always reflect the total distance you have travelled. The average velocity equation will give you a completely accurate reading when an object is in uniform motion, but when an object speeds up or slows down on its travels, $\vec{v}_{avg}$ becomes an estimate of the current velocity.



This graph shows the movement of a car driving from Winnipeg to Grand Beach, with a waypoint in Selkirk. You can see that there are two distinct slopes (or velocities) before and after passing through Selkirk. Clearly this car was not in uniform motion during the trip.



If you draw a straight line between the origin (0 km, 0 min) and endpoint (100 km, 95 min) of the graph, you can see the path the car would have taken if its velocity had been constant. When you use the equation for average velocity, you are calculating the slope of this new line.

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t} = \frac{d_2 - d_1}{t_2 - t_1}$$

$$\vec{v}_{\text{avg}} = \frac{100 \text{ km} - 0 \text{ km}}{95 \text{ min} - 0 \text{ min}} = \frac{1.05 \text{ km}}{\text{min}}$$

(You can convert the units from minutes to hours to give a more practical answer.)

$$\frac{1.05 \text{ km}}{\text{min}} \times \frac{60 \text{ min}}{1 \text{ h}} = \frac{63 \text{ km}}{\text{h}}$$

The average velocity during the trip to Grand Beach was 63 km/h. To get a more precise reading you would have to measure a smaller interval of time:

Average Velocity from Selkirk to Grand Beach:

$$\vec{v}_{avg} = \frac{100\text{ km} - 40\text{ km}}{95\text{ min} - 25\text{ min}} = \frac{60\text{ km}}{70\text{ min}} = \frac{0.86\text{ km}}{\text{min}} \text{ or } \frac{52\text{ km}}{\text{h}}$$

Understanding Instantaneous Velocity

If you kept measuring smaller and smaller intervals of time, eventually you would find **instantaneous velocity**—the velocity of an object at a specific instant of time.

$$\text{Instantaneous Velocity} = \frac{\text{position}}{\text{instant of time}}$$

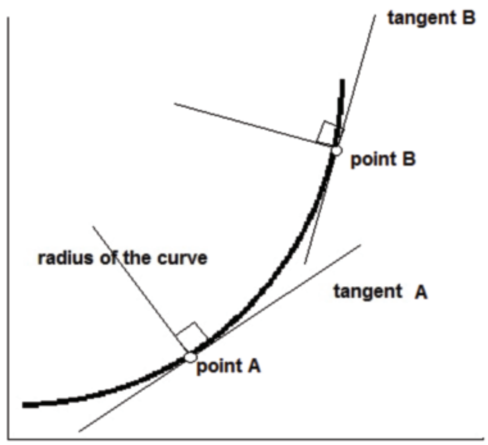
$$\vec{v}_{inst} = \frac{d}{t}$$

When the slope of a position-time graph is constantly changing, instantaneous velocity readings provide far more accurate measurements of velocity. To find out how to measure instantaneous velocity, read pages 16 and 17 of the *In Motion* booklet.

Looking at Accelerated Motion

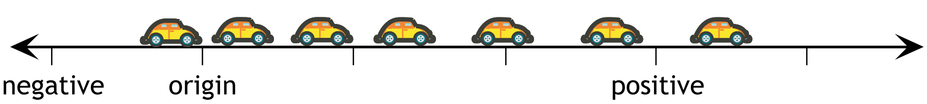
In accelerated motion, objects are speeding up or slowing down. Therefore, the velocity is not constant. Since the slope on a P-T graph gives the velocity, a changing velocity will mean that the slope on the P-T graph must also change. A line with a changing slope is a curve. The slope of the curve at a given moment will calculate the velocity at that instant, the **instantaneous velocity**.

But, how do you take the slope of a curve? The way to do this is to draw a tangent. A tangent is a straight line that intersects the curve at one point and is at right angles to the radius of that curve.

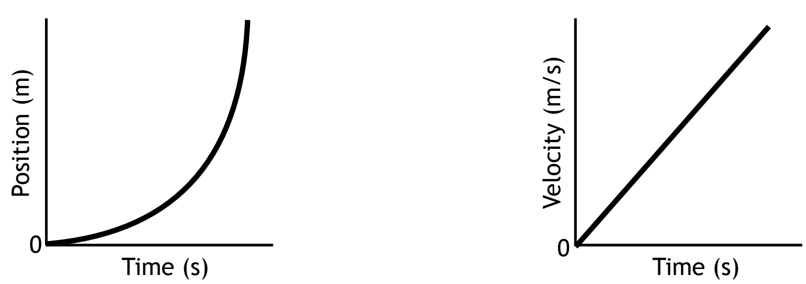


To correctly draw tangents we need calculus, but in high school we can draw a close estimate of the tangent using a ruler. In this example, we have drawn two tangents at points A and B. If we compare the two tangents, we see that tangent B is steeper (has a greater positive slope) than tangent A. In a P-T graph, this means that slope of the curve is becoming steeper (more positive) with time. Because tangents are straight lines, we can even calculate their slopes to get numerical answers from a curved graph.

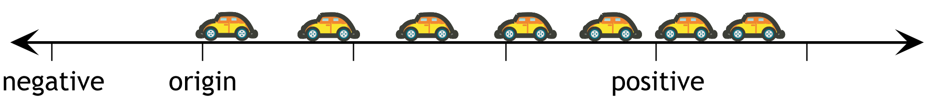
So, if the slope on a P-T graph becomes more positive (the line becomes steeper), the instantaneous velocities are becoming more positive (larger speed in the positive direction).



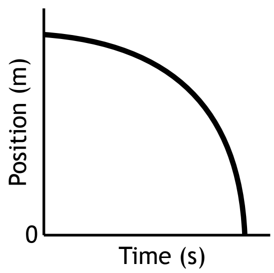
The slope at 0 seconds is 0 m/s. The slope of the graph is becoming more positive (farther in the positive direction). The velocity is increasing in the positive direction (speeding up in the positive direction). This is accelerated motion.

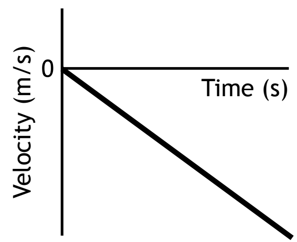


Remember that velocity is a vector quantity, and has magnitude and direction. When you see a velocity such as –10 m/s this means that an object is travelling at 10 m/s in the direction designated as "negative."



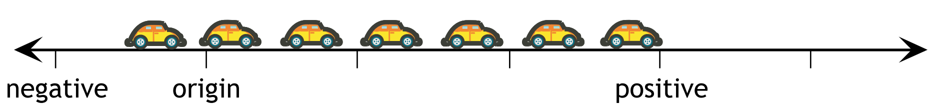
Here, the car starts at rest to the right of the origin. It begins moving towards the origin, moving faster over time. Notice how the slope on the P-T graph falls sharper over time, until it is nearly vertical. This indicates an increase in speed. On the corresponding V-T graph, velocity increases at a constant rate.



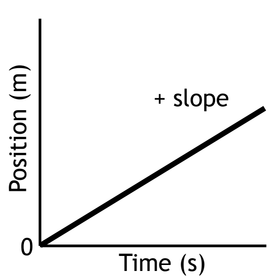


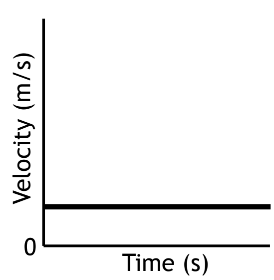
Acceleration at a Glance

Position-time graphs for uniform motion are straight-line graphs. The slope of a position-time graph gives the velocity. If the line is straight, the velocity is uniform over that time interval. In these cases, since the velocity is uniform, there is no acceleration.

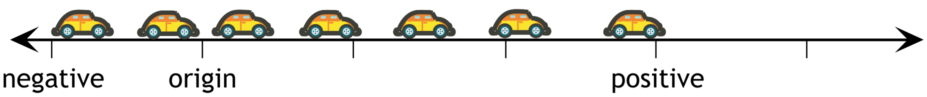


The slope of the P-T graph is positive with a low value. The velocity has a low positive value. The speed is low and the direction is positive. The line is straight so the velocity is constant. The object is moving away from the origin to the right.

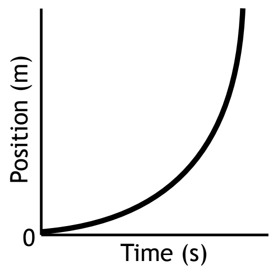


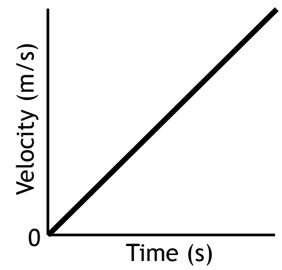


If the movement is accelerated, the graphs of position-time are curved. On these graphs, the slope of the line still gives the velocity, but only the velocity at that instant (the instantaneous velocity). Since the slope of the curve on the position-time graph is always changing, so too is the instantaneous velocity always changing from one instant to the next instant in time. In these cases, the velocity is non-uniform or changing. There is an acceleration.



The slope at 0 seconds is 0 m/s. The slope of the P-T graph is becoming more positive (larger in the positive direction). The velocity is increasing in the positive direction (speeding up in the positive direction). This is accelerated motion.





Acceleration occurs when an object speeds up or slows down while moving in a straight-line path. **Acceleration** is the rate at which an object changes velocity over time. It is a vector quantity, meaning that the direction in which acceleration acts is important.

Time (s)	Velocity (m/s)
0	0
1	3
2	6
3	9
4	12

The chart on the left shows that the velocity of an object is changing with time. For each second, the velocity changes by 3 m/s. The acceleration of this object is 3 m/s/s. Since the acceleration is always 3 m/s/s, the acceleration is a uniform acceleration.

Acceleration is calculated using the following relationship:

$$\text{Average acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

$$= \frac{\text{final velocity – initial velocity}}{\text{time interval}}$$

In **symbols**, the following equation is used to calculate acceleration:

$$\vec{a}_{\text{ave}} = \frac{\vec{v}_{\text{final}} - \vec{v}_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

$$\vec{a}_{\text{ave}} = \frac{\Delta\vec{v}}{\Delta t}$$

For example, the average acceleration for the time interval from 1 s, when the velocity is 3 m/s, to 4 s, when the velocity is 12 cm/s, would be found as follows:

$\text{time}_{\text{initial}} = 1\text{ s}$ $\text{velocity}_{\text{initial}} = 3\text{ m/s}$

$\text{time}_{\text{final}} = 4\text{ s}$ $\text{velocity}_{\text{final}} = 12\text{ m/s}$

$$\begin{aligned}\vec{a}_{\text{ave}} &= \frac{\Delta\vec{v}}{\Delta t}\\ &= \frac{12\text{ m/s} - 3\text{ m/s}}{4\text{ s} - 1\text{ s}}\\ &= \frac{+9\text{ m/s}}{3\text{ s}}\\ &= +3\text{ m/s/s or }3\text{ m/s}^2\end{aligned}$$

Acceleration is expressed in units of velocity over time. The units of velocity and time determine the units of acceleration.

Typical units of acceleration are:

$$\frac{\text{velocity}}{\text{time}} = \frac{\text{m/s}}{\text{s}} = \text{m/s/s or m/s}^2$$

or

$$\frac{\text{velocity}}{\text{time}} = \frac{\text{km/s}}{\text{s}} = \text{km/s/s or km/s}^2$$

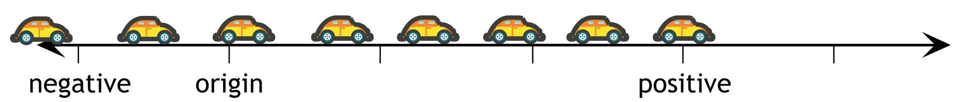
Remember, acceleration is a **vector**. Always include a direction with your answer.

Acceleration-Time Graphs

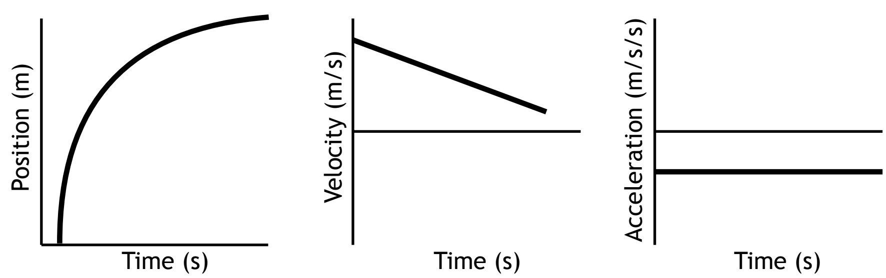
Just like with position and velocity, you can draw a graph to show the change in acceleration over time.

Acceleration-time graphs are very similar to velocity-time graphs:

- the further away your line is from the X-axis, the greater the acceleration
- if the direction of acceleration is positive, then your line is above the X-axis
- if the direction of acceleration is negative, then your line is below the X-axis
- a horizontal line indicates constant acceleration



The car is moving to the right, but the velocity is decreasing. The acceleration is opposite to the motion.



The Meaning of the Sign of Acceleration

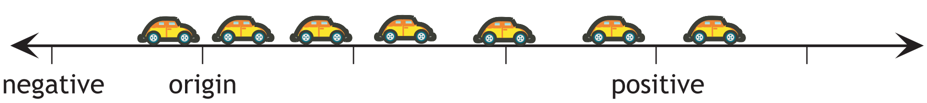
The sign of the acceleration gives the direction in which the acceleration acts. A positive acceleration acts to the right, and a negative acceleration acts to the left. A positive acceleration does not always mean that an object is speeding up. Sometimes an object with a positive acceleration is slowing down. To make sense of the sign of acceleration and whether an object is speeding up or slowing down, you must also consider the sign of velocity. The following table summarizes the different situations that can occur.

Sign (Direction) of Velocity	Sign (Direction) of Acceleration	What You See
+ (right)	+ (right)	Moving right, speeding up
+ (right)	– (left)	Moving right, slowing down
– (left)	– (left)	Moving left, speeding up
– (left)	+ (right)	Moving left, slowing down

At first, the table may look very confusing. It is better to remember a simple rule. You will notice that if the velocity and acceleration have the ***same*** sign, the object will be ***speeding up***. If velocity and acceleration have ***opposite*** signs, the object will be ***slowing down***.

Learning Activity 3.6: Velocity and Acceleration

1. Use the graphic below to answer the following.

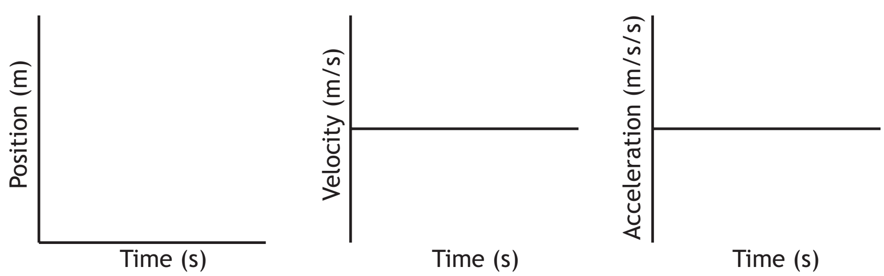


   a. Describe the motion of the car.

   b. What is the sign of the velocity?

   c. What is the sign of the acceleration?

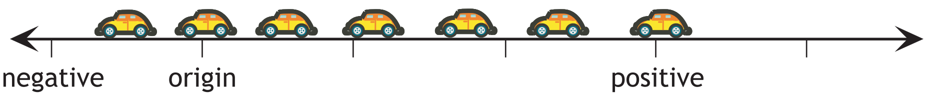
   d. Sketch the lines for the position-time graph, the velocity-time graph, and the acceleration-time graph that describe this motion.



continued

Learning Activity 3.6 (continued)

2. Use the graphic below to answer the following.

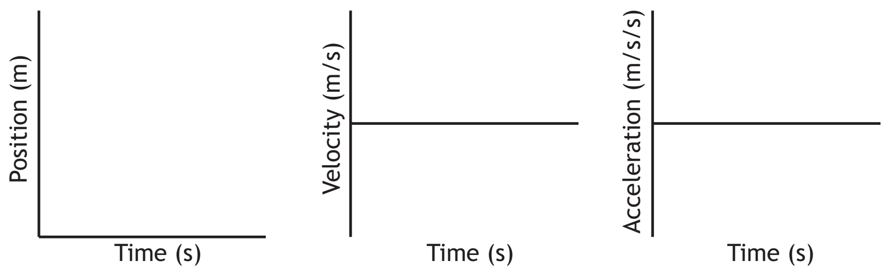


a. Describe the motion of the car.

b. What is the sign of the velocity?

c. What is the sign of the acceleration?

d. Sketch the lines for the position-time graph, the velocity-time graph, and the acceleration-time graph that describe this motion.



3. Use the data in the table below to answer the following.

Time (s)	Velocity (m/s)
0	10
1	9
2	8
3	7
4	6
5	5

a. Describe the motion of the object.

b. What is the sign of the velocity?

c. What is the sign of the acceleration?

continued

Learning Activity 3.6 (continued)

4. Use the data in the table below to answer the following.

Time (s)	Velocity (m/s)
0	–4
1	–8
2	–12
3	–16
4	–20
5	–24

a. Describe the motion of the object.

b. What is the sign of the velocity?

c. What is the sign of the acceleration?

5. Use the data in the table below to answer the following.

Time (s)	Velocity (m/s)
0	–11
1	–9
2	–7
3	–5
4	–3
5	–1

a. Describe the motion of the object.

b. What is the sign of the velocity?

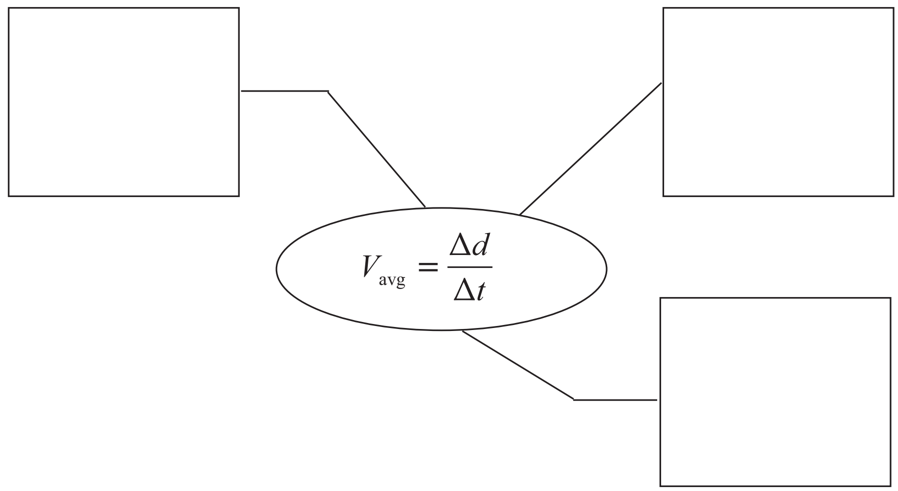
c. What is the sign of the acceleration?

continued

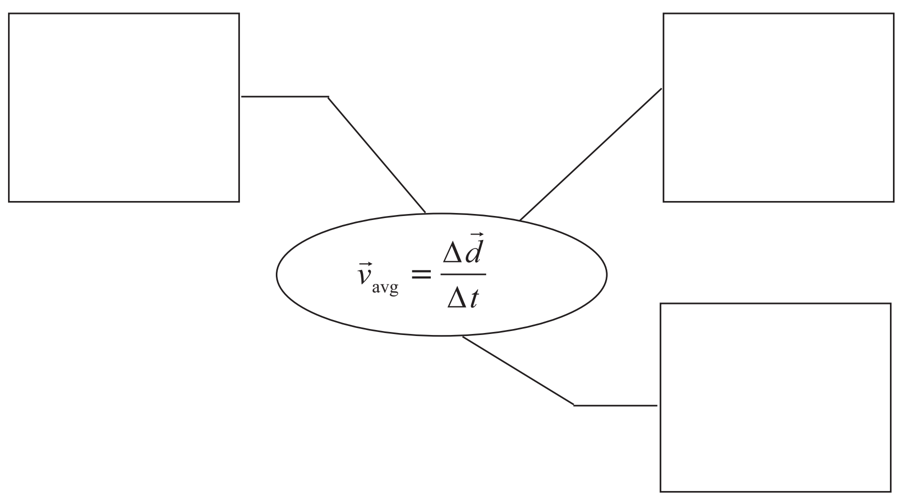
Learning Activity 3.6 (continued)

6. For each symbol in the following equations, give the name of the quantity, a definition, its unit, and whether it is a vector or scalar. Write the information around each rectangle.

   a.



   b.



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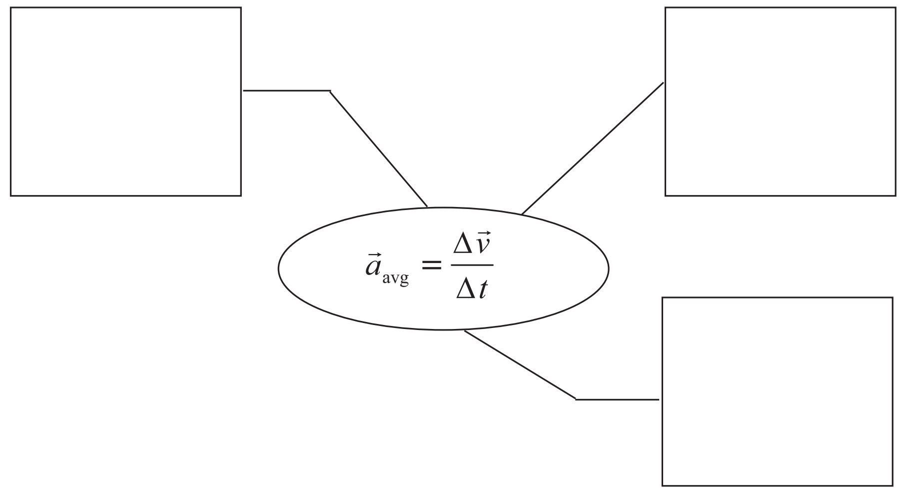
c.



Construct a Velocity-Time Graph

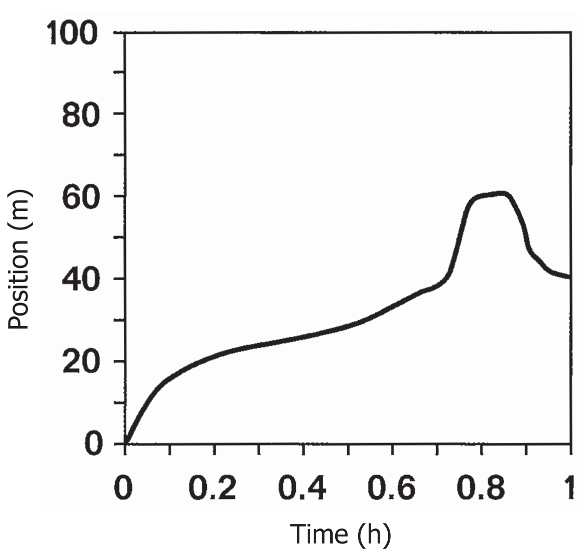
7. From the graph below, calculate the average velocity between the following points and comment whether or not the average velocity closely approximates the instantaneous velocity at the midpoint of the interval.

   a. t_1 = 0 h and t_2 = 0.1 h

   b. t_1 = 0.2 h and t_2 = 0.4 h

   c. t_1 = 0.6 h and t_2 = 0.8 h

Position versus Time



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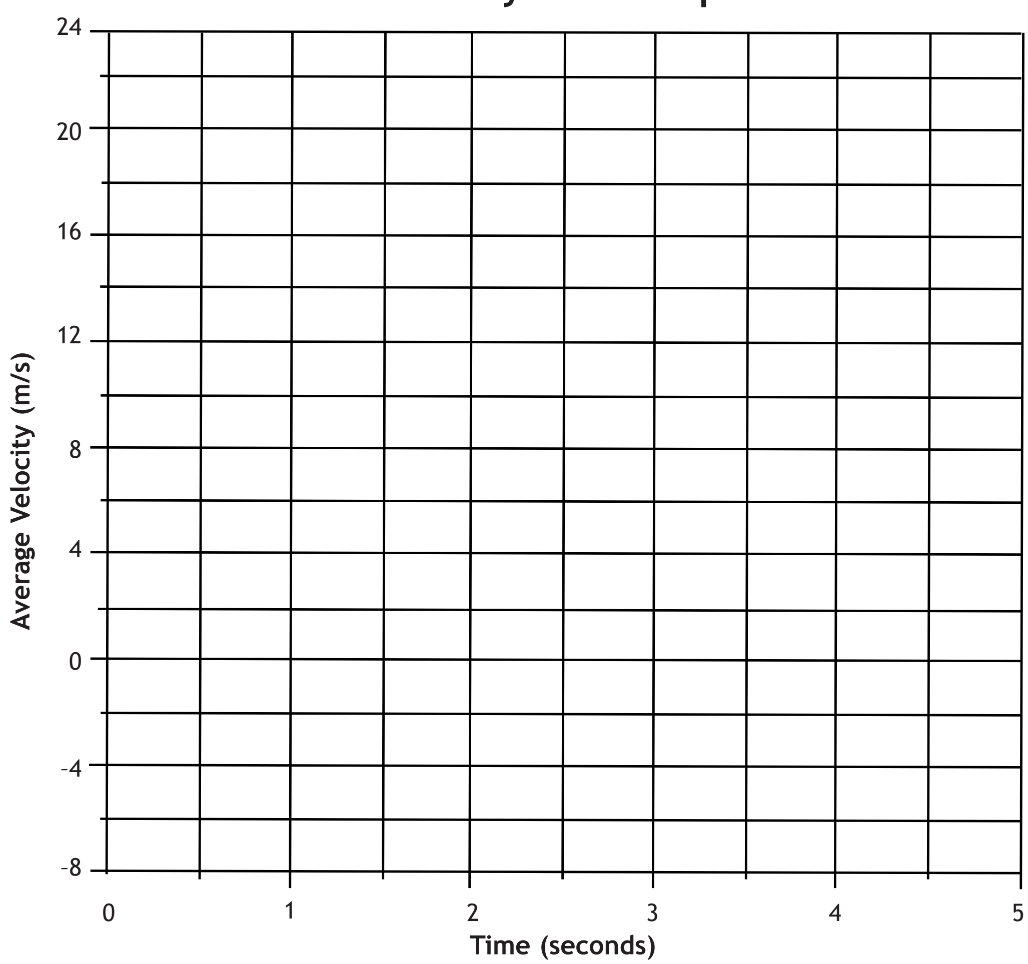
8. The table below shows the velocity in metres-per-second of four different cars. Draw the velocity-time graph for each vehicle on the provided graph.

	Time					
		0.0	**1.0 sec**	**2.0 sec**	**3.0 sec**	**4.0 sec**
Velocity (m/s)	**Car A**	0.0	4.0	8.0	12.0	16.0
	Car B	24.0	24.0	24.0	24.0	24.0
	Car C	24.0	16.0	8.0	0.0	–8.0
	Car D	2.0	4.0	6.0	8.0	10.0

Velocity-Time Graph



continued

Learning Activity 3.6 (continued)

9. Find the acceleration in each case.

   a. A car increases its velocity from 0 km/h to 20 km/h in 6 seconds.

   b. A train crosses a boulevard at 10 km/h and begins accelerating as it heads out of the city. Thirty minutes later it crosses another road at 60 km/h. What is the average acceleration of the train during this period of time?

   c. A truck travelling west at 50 km/h pulls out to pass another vehicle that is moving at a constant velocity. The truck increases its velocity to 60 km/h in 6 seconds.

Check the Learning Activity Answer Key found at the end of this module.

Summary

When an object is in accelerated motion, it can speed up or slow down as it travels. This means that finding the average velocity of a long trip may give you very different results when compared with the instantaneous velocity during a very short period of time. Finding the acceleration of a moving object will help you to understand just how quickly (or slowly) an object is changing its velocity. In the next lesson you will step back into history and discover just how humans discovered all that they do about motion.

LESSON 6: ARISTOTLE, GALILEO GALILEI, AND SIR ISAAC NEWTON ON MOTION IDEAS

Lesson Focus

After completing this lesson, you will be able to

- ❑ discuss Aristotle's contribution to the concepts of force and natural motion
- ❑ compare Aristotle's view of motion with that of Galileo
- ❑ summarize Galileo's contribution to our knowledge of motion
- ❑ explain Newton's first law of motion

Key Words

- Galileo Galilei
- Aristotle
- Sir Isaac Newton

Introduction

If you had been born 500 years ago and studied physics in school, you would have learned a very different set of explanations for how and why objects move the way they do. The study of physics is marked by a history of scientists refining and redeveloping theories of motion. This lesson will introduce you to three of history's most influential physicists: Aristotle, Galileo, and Isaac Newton.

Aristotle's Theory of Motion (384 to 322 BC)

Aristotle was a Greek philosopher who devoted himself to investigating an amazing range of subjects, including biology, politics, and psychology. In the field of physics, Aristotle was very curious about how objects would move if there were no outside forces (such as gravity) acting on those objects. Through his observations and logical reasoning, Aristotle developed the following generalizations about motion:

- Falling bodies fall at a constant speed.
- Falling bodies fall faster if they are heavier.
- Falling bodies fall slower if they are met by some sort of resistance.
- Every object on Earth has a "natural motion," or attraction, toward the centre of Earth (we now call this a **gravitational** attraction).
- You must apply a **force** to move an object, and keep applying that force to keep the object in motion.

Galileo on Motion (1564 to 1642 AD)

Galileo Galilei was a true "Renaissance thinker"—a man of many talents. Not only was he a philosopher, he was also an accomplished mathematician and astronomer who performed experiments to explore his theories. Galileo did not agree with the physics that Aristotle proposed and worked to disprove some of Aristotle's theories. Galileo developed the following generalizations about motion:

- Once you stop applying force to an object, friction will slow the object down to a complete stop.
- A body in motion will continue in motion at the same speed unless a force acts on the object from the opposite direction.
- In a vacuum, with all forces of friction removed, all objects fall at the same speed regardless of their mass.
- An object falling freely through the air or rolling freely down an inclined plane will undergo a constant acceleration.

Galileo's Thought Experiment

One of the experiments Galileo performed to explain his theories of motion involved rolling objects down a U-shaped incline and measuring the height to which they travelled. Galileo predicted that in an ideal scenario, the object would accelerate along the incline until it returned to its original height.

Review pages 23 to 25 of the *In Motion* booklet to learn more about Galileo's experiment, and how you can replicate it for yourself.

Learning Activity 3.7: Student Investigation

This is an optional experiment, since supplies or equipment may not be available to you. If you are attending school, ask a teacher whether this experiment can be conducted in the science lab.

After you have completed the tables, answer the Data Analysis questions carefully and thoughtfully. If supplies or equipment are not available to you, use the sample data to help you answer the questions.

Purpose

Galileo imagined a scenario where an object was rolled down a U-shaped incline. He predicted that in an ideal scenario, the object would continue to accelerate along the track until it had returned to its original height.

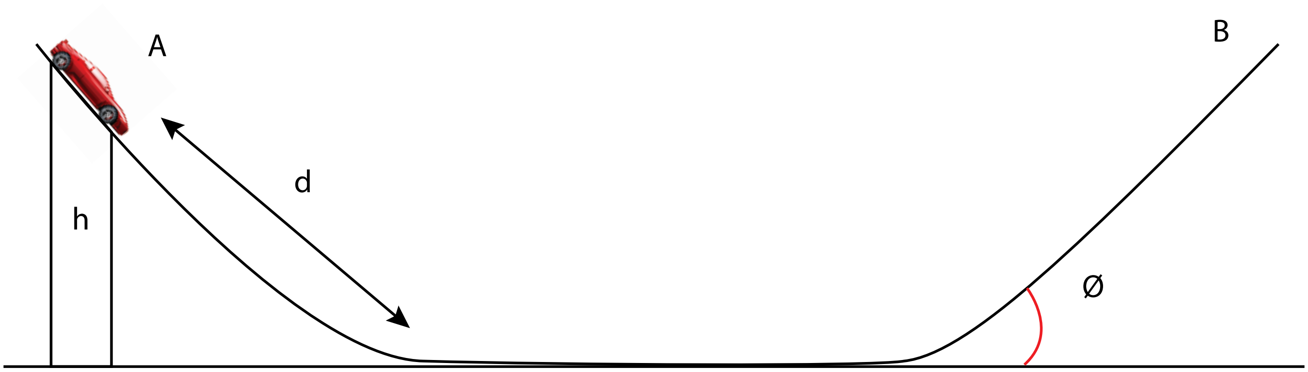
This experiment will determine whether Galileo's prediction can be recreated using a real world model.

Materials

- small toy car
- metric ruler
- protractor
- long, flexible material for a ramp (plastic, cardboard)
- support pillars, x 2

Procedure

1. Using a metric ruler, mark your material into quarter sections. Secure it on a flat surface so that the centre will not move. Label the endpoints A and B.
2. Bend your ramp material into a smooth, U-shaped inclined plane. Secure it in position by placing a support pillar underneath each incline. Both inclines should rest at the same height.
3. Measure the vertical height of the endpoints with the metric ruler, as well as their angle with the ground. Record these measurements on Data Table 1.



4. Place the toy car on endpoint A and release it down the incline. Record the point to which it travels before stopping and reversing direction. Using a metric ruler, measure the height of this point. Repeat this step at least five times, and record the **average height** in Data Table 1.
5. Adjust the support beneath endpoint B so that it rests lower than endpoint A. Record the new angle Incline B makes with the surface in Data Table 1.
6. Repeat Steps 4 and 5, collecting data.

Data Collection

Data Table 1

Angle of Incline A:	
Height of Incline A:	
Angle of Incline B:	Average Height Travelled up Incline B:

Sample Data

Data Table 1

Angle of Incline A:	
Height of Incline A:	
Angle of Incline B:	Average Height Travelled up Incline B:
30°	35 cm
25°	34 cm
17°	34 cm
10°	34 cm

Data Analysis

1. What patterns did you notice in your data? Was there any connection between the angle of Incline B and the average height that the car was able to rise?
2. In an ideal scenario, Galileo predicted that objects travelling on a U-shaped incline would return to its original height. Do your results agree with this prediction? If not, how can you explain this difference?

Check the Learning Activity Answer Key found at the end of this module.

Galileo's Results

Galileo was not always correct, of course. He corrected and modified many errors in his theories along the way and is credited with many important discoveries in the emerging sciences of physics and astronomy.

Newton and Motion

Isaac Newton described acceleration as an imbalance in forces. For example, if there is a force acting on your right side but there is a stronger force acting on your left side, you will be moved to the right. Newton devised a law of physics that is still accepted today. Newton's first law of motion is the following:

> An object at rest stays at rest, and an object in motion stays in motion in a straight line and at constant velocity, unless the object is acted upon by an external and unbalanced force.

This characteristic of matter to resist changes in motion is called **inertia**. This is why Newton's first law is often referred to as Newton's law of inertia.

Learning Activity 3.8: Theories of Motion

	Aristotle	Galileo	Newton
How were his theories* similar to the others?			
How were his theories* different from the others?			
How do these theories* relate to motion of a moving car?			

* **Note:** Here, we use the term *theory* in a very non-scientific way, meaning a set of prior beliefs that help to explain new phenomena.

Check the Learning Activity Answer Key found at the end of this module.

Notes

Lesson 7: The Link between Force and Motion

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe inertia in a variety of situations
- ❑ explain how an object's mass affects its inertia
- ❑ describe how the mass of an object affects the amount of force necessary to move that object

Key Words

- force
- Newton's second law
- mass

Introduction

Galileo and Aristotle are fascinating men and worthy of further study, but for now you will focus on Sir Isaac Newton and the three laws of motion. You will also discover just what exactly a *force* is.

A Recap of Force

The term *force* has many meanings in the English language. It can be used to describe military power, physical violence, willpower, or authority. In physics, a **force** is defined as any influence that alters or causes motion. You exert a force whenever you push or pull an object.

- Force is a vector quantity. It has magnitude, and it acts in a particular direction. The force of gravity, for example, is directed towards the surface of Earth.

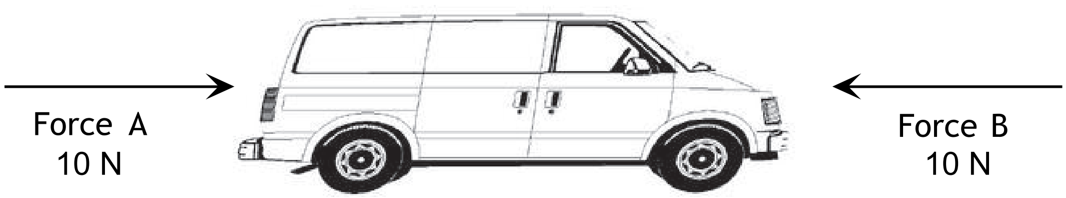
- As a vector, forces acting in the same direction will strengthen each other, while forces acting in opposite directions will cancel out one another.
- Forces are measured in a unit called the newton (N), a tribute to Sir Isaac. Gravity pulls on all terrestrial bodies with a force of 9.8 N.

After extensive study and experimentation, Sir Isaac Newton came to three conclusions about the motion of all objects. This lesson will review the first two.

Newton's First Law of Motion

An object at rest will remain at rest unless acted on by an unbalanced force. An object in motion will remain in motion in a straight line and at constant velocity, unless acted on by an unbalanced force.

The first law of motion explains how forces interact as vectors, and the results of these interactions on physical objects. In the diagram below, two forces are pushing against the minivan. Both exert 10 newtons against the vehicle, but each acts in the direction opposite to the other. To determine in which direction the van will move, all of the forces must be added together. This provides the **net force**, or total force acting on the minivan.



Net Force = Force A + Force B

or

$$\vec{F}_{net} = F_A + F_B$$

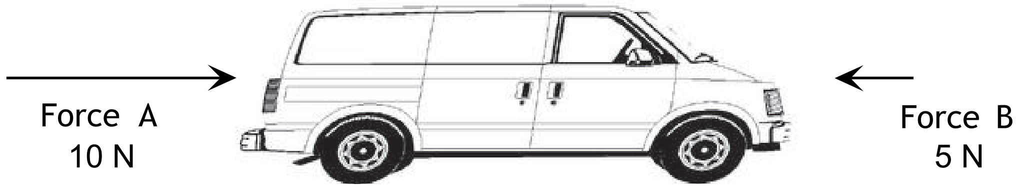
$$\vec{F}_{net} = 10\text{ N} + (-10)\text{N}$$

$$\vec{F}_{net} = 0\text{ N}$$

The net force acting on the van is 0 newtons. In other words, no one force is strong enough to overcome the other. The minivan is acted upon by **balanced forces** and, consequently, remains at rest.

When forces are **unbalanced**, that means there is a greater force in one direction than in another. When there are unbalanced forces acting on an object, this will cause the object to move in the direction of the stronger force.

The minivan below is acted upon by unbalanced forces and, consequently, moves in the direction of Force A, the stronger force.



$$\vec{F}_{net} = 10\text{ N} + (-5)\text{N}$$
$$\vec{F}_{net} = 5\text{ N}$$

A net force of 5 N moves the van to the right.

Newton's first law tells us that moving objects such as cars will slow down because a force is applied in opposition to their motion. They accelerate because a new force adds an extra push in their current direction.

Newton's Second Law of Motion

When a force acts on a mass, acceleration is produced. The greater the mass, the greater the amount of force needed to cause acceleration.

The second law of motion explains the relationship between an object's mass and the acceleration it experiences due to a force. It tells us that the more mass an object has, the more difficult it becomes to start, stop, or change that object's motion.

For example, it takes a great effort to push a piano across a room, but a piano bench will slide considerably easier. This is because the piano has a greater mass than the bench; a larger force must be applied to the piano in order accelerate it from rest.

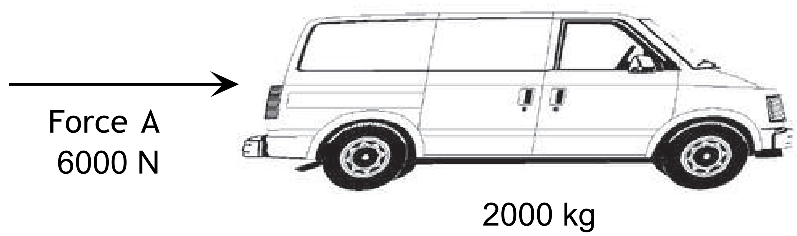
Newton's second law also applies to sports: consider how easy it is for a batter to send a baseball soaring through the air. Because the ball has a small mass even a gentle, underhand toss will accelerate it from rest. Can you imagine tossing a bowling ball with the same results as a baseball? The added mass makes it impossible.

Newton's second law can also be expressed as a mathematical formula:

Force = mass × acceleration

$$\vec{F} = m\vec{a}$$

Where $\vec{F}$ = the force acting on the object
And m = the mass of the object
And $\vec{a}$ = the acceleration of the object



If the minivan is acted upon by a net force of 6000 N to the right, and the average van has a mass of about 2000 kg, we can use Newton's second law to discover how rapidly the van is accelerating:

$$\vec{F} = m\vec{a}$$

$$\therefore \vec{a} = \vec{F}/m$$

$$\vec{a} = 6000 \text{ N} / 2000 \text{ kg}$$

$$\vec{a} = 3 \text{ m/s}^2$$

The minivan is accelerating towards the right (positive) at 3 metres-per-second^2.

Learning Activity 3.9: Forces in Action

1. Explain why a person wearing a cast on one leg becomes more tired than usual by the end of the day.
2. Suggest reasons why large vehicles such as vans and trucks tend to have larger engines and higher rates of fuel consumption than smaller and more compact cars.
3. Use Newton's laws to explain why people in a car often get neck injuries like whiplash when struck from behind.
4. Explain why small rabbits can often escape bigger and faster bobcats in pursuit by zigzagging as they run.
5. Predict when serious injuries are more likely to occur: when a car crashes into a large tree or into a wooden fence.

Check the Learning Activity Answer Key found at the end of this module.

Summary

Newton's first law of motion explains

- that stationary objects are held in place by equal, opposing forces
- that accelerating objects experience a net force that favours or opposes their current motion

What can you summarize from the second law of motion?

- If you apply a greater force, there will be greater acceleration (be that speeding up or slowing down).
- The more massive an object becomes, the greater the force necessary to change its speed and its acceleration.
- Forces are capable of changing the direction of an object's motion.

Notes

Lesson 8: Effects of Inertia on Car Collisions

Lesson Focus

After completing this lesson, you will be able to

- ❑ define inertia in terms of an object at rest or in uniform motion
- ❑ describe the relationship between the speed of a car and the distance travelled by an unrestrained passenger in a car crash

Key Words

- inertia
- velocity
- acceleration

Introduction

Imagine that you are riding your bike home from school and you hit a deep rut in the road. Your front wheel dips suddenly, causing the bike to come to an abrupt halt, and you are sent forward over your handlebars. Why do you keep moving after your bike has come to a sudden stop? Would your injuries be worse if you were travelling faster before you hit that bump in the road?

Inertia and the Laws of Motion

Newton's first law of motion is sometimes called the "law of inertia." **Inertia** is the tendency of an object to resist change. If an object is at rest, it tends to remain at rest. Likewise, objects moving at constant velocity tend to continue moving at that velocity.

Have you ever ridden in a car or a bus that had to stop abruptly? As the vehicle screeched to a halt, you may have felt your body being pulled away from your seat and towards the front of the car. If you were wearing your seat belt, you probably felt it dig into your chest, keeping you from flying forward. Although the vehicle came to a stop, your body kept moving forward. The **inertia** of your body resisted the change in motion.

The next time you are a passenger in a car, take a box with a marble inside that can roll freely, and put it on the seat beside you. As the car speeds up and slows down, keep an eye on your marble and make note of any motion that occurs. You should notice it rolling forward as the car stops. This is also a demonstration of inertia in action.

Inertia and Car Collisions

You are a passenger in a car travelling south at 45 km/h. Another car darts out into the intersection and you do not have enough time to stop. When the cars collide, you as a passenger are still travelling with the momentum of the moving car. Unless you are wearing your seatbelt, you will move forward in the car at a speed of 45 km/h until you collide with the dashboard, which will cause you to stop. Alternatively, you may be thrown from the car through the window at the same speed the car was travelling before the collision occurred. Thus, in every accident on the road, there are actually two collisions:

- what collides with the car, causing it to change direction or to stop
- what the passenger then collides with, causing her/him to stop

We know that the **distance a passenger is thrown from a moving car is proportional in some way to the velocity of the car before collision**. Simply put, this means that the faster the car is travelling, the farther a passenger may be thrown in the case of a car collision. We can determine the distance a thrown passenger will travel in this type of scenario if we know the velocity of the vehicle (before collision) and the interval of time the passenger travels through the air.

Let’s try to demonstrate this with a simple learning activity, using marbles or small steel balls.

Learning Activity 3.10: The Velocity of a Car on an Inclined Plane

This learning activity involves a hands-on experiment. If you are attending school, ask a teacher whether this experiment can be conducted in the science lab.

If you do not have the equipment for this experiment, you should still read through the procedure and use the sample data to answer the follow-up questions carefully and thoughtfully. This learning activity will be very helpful for the upcoming assignments.

Set up your ramp according to the instructions on page 28 of *In Motion*. You will need the ramp that you used in Learning Activity 3.7 and a marble. Remember that you need a ramp long enough to give you five or six different starting points that are proportionately spaced out. Once you have everything set up, marked, and measured, ***do not move*** the ramp. Keep the ramp at the same angle for all your trials.

Keep the ramp, as you will need to use it again for your Module 3 assignments.

Note: You may find it difficult to release the marble and, at the same time, watch where it falls. See if your learning partner can help you make these observations.

It is important to find the position on the ramp that gives the required distance along the floor. For example, find how far up the ramp you must release the marble for it to land 12 cm from the edge of the table (as measured along the floor).

1. Write a concluding paragraph (i.e., what can you conclude, based on your observations?).
2. How could seat belts and air bags be effective means of saving lives in car collisions?

continued

Learning Activity 3.10 (continued)

3. Record your observations here (suggested results are also included):

Suggested Starting Point on the Ramp (v)	Sample Values: Distance the Marble Travelled through the Air (d, Measured along Floor)	My Values: Distance the Marble Travelled through the Air (d, Measured along Floor)
5 cm (1 v)	1 d = 12 cm	1 d = __ cm
20 cm (2 v)	2 d = 24 cm	2 d = __ cm
45 cm (3 v)	3 d = 36 cm	3 d = __ cm
80 cm (4 v)	4 d = 48 cm	4 d = __ cm
125 cm (5 v)	5 d = 60 cm	5 d = __ cm

Check the Learning Activity Answer Key found at the end of this module.

Summary

Objects resist change to their motion because of their inertia. In a moving car, all passengers and cargo inside of the car are moving at the same speed as the car. However, they do not slow down at the same time as the car itself, creating the need for safety harnesses. The previous learning activity will demonstrate how the speed of a moving object affects the distance it travels.

Assignment 3.1: Inertia and the Unrestrained Passenger (14 marks)

Now that you have done some exploration into the relationship between the distance an unrestrained passenger travels in a collision and the speed of the vehicle, it's time to put your knowledge into practice. In this assignment, you will be observing what happens to the unrestrained passenger when a moving car comes to an abrupt stop.

There are two different ways that you can complete this assignment, depending on whether or not you have access to the materials needed to complete the experiment. These materials include the following: small toy car, long flexible material for ramp, barrier (such as a book), metric ruler, stopwatch, support pillar (such as a stack of books), and modelling clay to make a toy passenger for the toy car.

1. If you do not have access to the materials, you can view the *Grade 10 Science Inertia and the Unrestrained Passenger* video found in the learning management system (LMS). and complete the assignment that way. If you do not have access to the Internet, or if you need a copy of the video, contact the Distance Learning Unit at 1-800-465-9915.
2. If you do have access to the materials, you can perform the investigation yourself.

Introduction

This assignment involves examining the effects of vehicle collisions. You are responsible for

- reading through the assignment description and familiarizing yourself with the purpose of this activity

- setting up a ramp to be used for an experiment OR watching the video experiment, *Inertia and the Unrestrained Passenger*

- filling out Table A: Distance Records (*2 marks*)
- plotting data on Graph A: Inertia and the Unrestrained Passenger (*2 marks*)
- answering the follow-up questions 1 to 4 (*10 marks*)

Objective

In this assignment, you will be observing what happens to an unrestrained passenger when their vehicle comes to an abrupt stop. Auto manufacturers regularly evaluate the safety of their vehicles using crash-test dummies; here, you will construct your own mannequin and send it on a high-speed crash.

There are two different ways that you can complete this assignment:

- Collect the required materials and build your own experimental apparatus (a ramp similar to the one used in Learning Activities 3.7 and 3.10).
- If you do not have access to the necessary materials, you can watch the *Grade 10 Science Inertia and the Unrestrained Passenger* video and complete the assignment using the in-video data.

What You Need

- ramp (a long, flat surface that can be raised on an angle)
- barrier (a small block or book)
- metric ruler
- toy car
- modelling clay "passenger"

Procedure

1. Set up the ramp on the floor with a barrier at the bottom. The barrier should be sturdy enough to stop the toy car when it comes down the ramp, but short enough that the clay "passenger" can fly over the barrier. Make sure there is plenty of space in front of your ramp.

continued

2. Mark three points on your ramp from where you will release your car. If you completed Learning Activity 3.10, you may wish to use points 1v, 2v and 3v again.
3. Sculpt your modelling clay into a passenger and rest it on top of the toy car.
4. Release the toy car from the point closest to the bottom of the ramp. This point corresponds to Speed 1 on Table A: Distance Records.

Note: As you use points further up your ramp, the speed increases. You do not need to calculate speed, but you do need to know that the car will gain speed with distance. This means that the point closest to the top of your ramp will be Speed 3 on Table A, and should be the fastest speed you will observe of your three trials.

5. Measure the distance the unrestrained passenger travelled from the barrier to the point where the passenger landed. Record this information under the heading "Trial #1." Repeat steps 3 to 5 two more times for point A, recording the information under the headings Trial #2 and Trial #3.
6. Calculate the average distance the unrestrained passenger travelled by adding the three trials together and dividing by 3.

   Example:

   Trial #1—3 cm

   Trial #2—3.2 cm

   Trial #3—2.9 cm

   Average distance travelled would be: $\frac{3 + 3.2 + 2.9}{3}$ = 3.03 cm.

7. Repeat the same steps above for the other two reference points along your ramp. Continue using the next closest point to the barrier, so that Speed 3 would be the farthest (at the top of the ramp).

continued

Assignment 3.1 (continued)

Data Collection

Table A: Distance Records (*2 marks*)

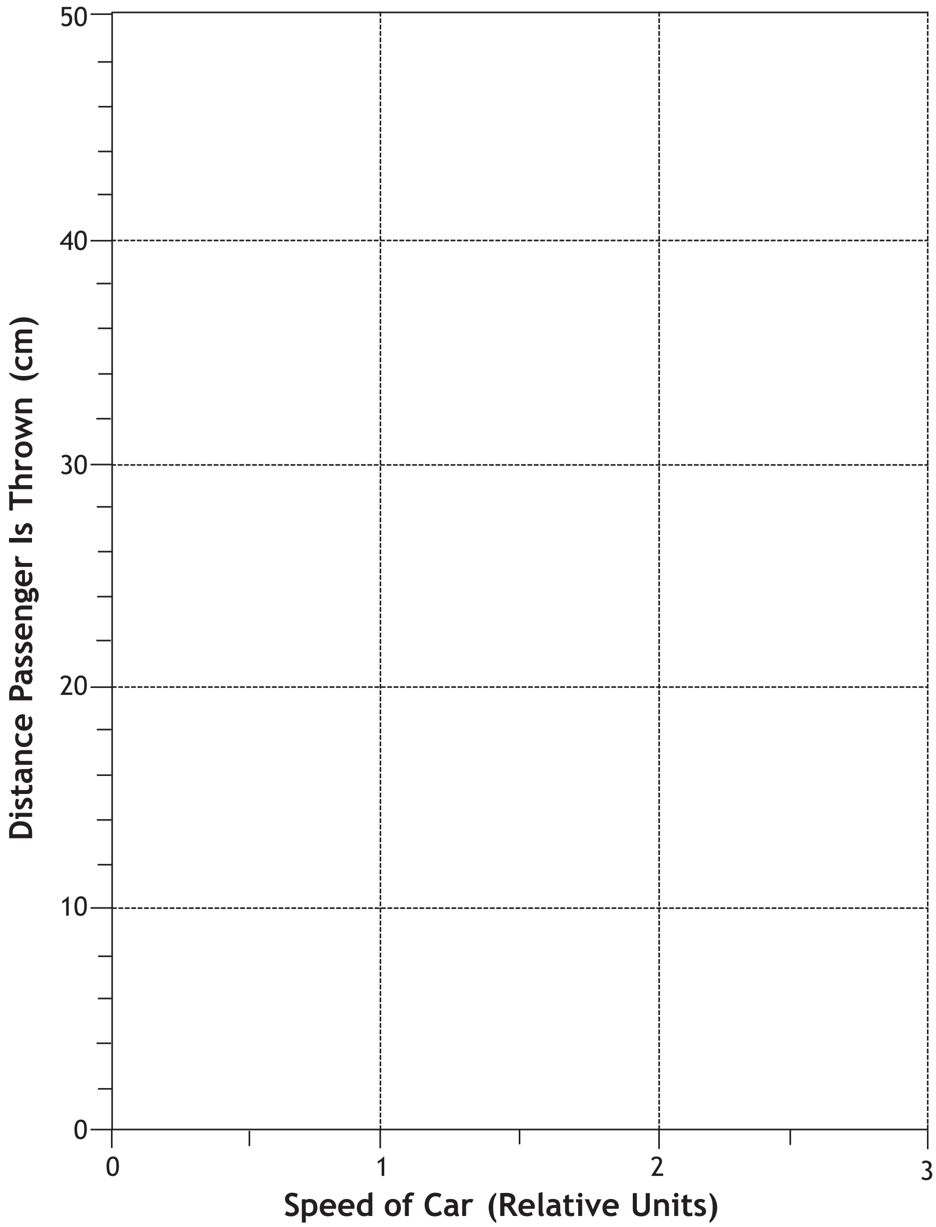
Speed	Trial #1	Trial #2	Trial #3	Average Distance the Occupant Is "Thrown" (cm)	Comments
1					
2					
3					

continued

Assignment 3.1 (continued)

8. Graph the average distance the occupant was thrown versus the speed of the car.

Graph A: Inertia and the Unrestrained Passenger (*2 marks*)



continued

Assignment 3.1 (continued)

Follow-up Questions

1. What does your graph tell you about the relationship between the distance an unrestrained object is "thrown" and the speed of the vehicle? (*2 marks*)

2. Are there any factors (besides speed) that affect the distance the occupant is thrown from trial to trial? (*2 marks*)

3. Using the information from Lesson 7 and the data from your experiment, explain why a person standing in a bus falls backward when the bus moves forward, and falls forward when the bus stops. (*3 marks*)

4. Using Newton's laws of motion, explain how a seat belt and an air bag help protect passengers in a car accident. (*3 marks*)

continued

Assignment 3.1 (continued)

To be eligible for full marks you must submit

- completed copy of Table A: Distance Records (*2 marks*)
- completed copy of the Graph A: Inertia and the Unrestrained Passenger (*2 marks*)
- questions 1 to 4, completed (*10 marks*)
- **Total: 14 marks**

Note: Hang on to your ramp. It can be reused in Assignment 3.3.

Notes

Lesson 9: Newton's Third Law

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe Newton's third law
- ❑ describe the everyday applications of Newton's third law

Key Words

- action
- reaction
- force

Introduction

If you've ever been swimming in a lake or pool, maybe you've noticed how your body reacts to every little motion you make in the water. Think about it: when you push water away with your hands, your body ends up moving as well, only in the direction opposite of your push. Why does your body move when you apply force to the water? This lesson will explain these "action-reaction" forces and how they fit under Newton's third law of motion.

Newton's Third Law of Motion

Newton's third law is probably the most widely known but also the most widely misunderstood. It is generally stated as, "For every action, there is an equal and opposite reaction." To make this clearer, we should probably reword this to say, "For every force, there is an equal force that opposes it." What this means is that forces always occur in pairs.

The force that initiates the reaction is named the **action force**, and the force that responds to the initial action is called the **reaction force**.

The biggest misunderstanding people have is to mix up the action force with the results of the pair of forces. They fail to understand what exactly the reaction force is.

Consider this: When you walk, you push **backward** on the ground. To go faster, you push backward harder. If you are on wheeled transportation of some kind, the wheels push backward on the ground. Newton's first law says that you will accelerate more if more force is applied to you. The second law says that the more mass something has the more force is needed to accelerate it. So, what pushed or pulled you forward? Why do you go **forward** faster when you push backward harder? **Newton's third law** gives us the answer.

If you push backward on the ground, the ground pushes forward on you with equal force.

You move forward because the amount of force you apply to the ground (the whole planet Earth) is not enough to accelerate it backward very much. However, you have a very small mass compared to Earth, so you get a much greater acceleration forward. If you push harder backward, Earth pushes forward equally harder.

To use the terms of the third law: The action force is you pushing on Earth. The reaction force is Earth pushing on you. The result of this pair of forces that you observe is that you are accelerated in the direction Earth pushes on you much more than Earth is accelerated in the direction you pushed it.

Examples

1. You push on a door to open it.
   - **Action force:** You push on the door.
   - **Reaction force:** The door pushes on you.

   You feel this as resistance to your push. The heavier the door, the more resistance you feel.

   The **result** of this pair of forces is the door moves away from you.

2. You throw a baseball to your friend.
   - **Action force:** Your hand pushes the ball toward your friend.
   - **Reaction force:** The ball pushes back on your hand.

   The observed **result** of this pair of forces is that the ball accelerates toward your friend.

   Now think of throwing a bowling ball to someone. Because a bowling ball has much more mass than a baseball, you have to throw (action) much harder and you feel the resistance (reaction) much more. But, because the bowling ball has much less mass than you, it still moves in the direction you pushed, and you do not move in the direction it pushed you.

3. You hit a tennis ball with a racquet.
   - **Action force:** The racquet pushes the ball forward.
   - **Reaction force:** The ball pushes the racquet backward.

   Because the mass of you and the racquet is much more than that of the ball, the ball flies forward. You feel the impact of the ball pushing backward on the racquet.

Review page 39 of the *In Motion* booklet for more information on action-reaction forces.

Learning Activity 3.11: Action and Reaction Forces

1. Identify the action and reaction forces in the following situations. Also provide what the observed result of the pair of forces is and why this occurs.
   a. A hockey player pushes forward with her skates.
   b. You jump off of an untied canoe onto a dock.
   c. Gravity pulls on a hammer someone dropped.
2. In each of the following cases, sketch the situation and label the action-reaction pairs.
   a. a person leans against a wall
   b. a fish swims
   c. a skateboarder jumps
   d. a gun recoils
   e. a hockey player's slapshot
3. While driving down the road, a mosquito collides with the windshield of your car. Which of the two forces is greater: the force that the mosquito exerts on the windshield, or the force that the windshield exerts on the mosquito?
4. Two students are facing each other while standing on their skateboards. One student throws a large medicine ball to the other student. Describe what happens in terms of force and motion.

continued

5. In terms of action-reaction force pairs, explain why it is important to use helmets, elbow pads, knee pads, and other protective clothing when using skateboards or in-line skates.

Check the Learning Activity Answer Key found at the end of this module.

Summary

Every action has an equal and opposite reaction. Newton's third law of motion tells us that, when you push on the water in a lake or pool, the water will push back on your body, moving you through the liquid. Whether you are walking, rollerblading, skateboarding, or riding a bicycle, any forward motion you experience is because of a force you applied in the opposite direction.

Lesson 10: Momentum and Impulse, Part 1

Lesson Focus

After completing this lesson, you will be able to

- ❑ define momentum
- ❑ define impulse
- ❑ relate impulse to change in momentum for everyday situations

Key Words

- momentum
- impulse

Introduction

Have you ever noticed that while tobogganing down a steep slope, you have a hard time stopping? This is because of your momentum. In this lesson, you will investigate the concept of momentum and how you can increase and decrease momentum.

What is Momentum?

In physics, **momentum** is referred to as the **amount of motion** in an object. The greater the momentum of an object, the more difficult it will be to alter that object's motion. To bring any moving object to a stop, its momentum must be reduced to zero.

What determines an object's momentum? Put another way, what qualities of an object determine how it moves, and how difficult it can be to start, stop, or accelerate?

1. The first determining factor of momentum is an object's **velocity**. Fast-moving objects are difficult to stop. The faster you drive a car, the longer and harder you must brake before you come to a stop.

2. The second factor contributing to momentum is an object's **mass**. Think back to Newton's second law of motion: the greater the mass, the greater the amount of force needed to affect acceleration. Massive objects, even if they are moving slowly, are also difficult to stop. Think about whether you would rather stand in front of a mosquito travelling at 2 km/h or a locomotive moving at 2 km/h, and you should agree that mass contributes to momentum.

Since momentum is the amount of motion, it can be calculated with the following equation:

Momentum = Mass × Velocity

$$\vec{p} = m\vec{v}$$

Momentum is represented by the symbol **p**, and is measured in kilogram-metres-per-second [kg•m/s].

Learning Activity 3.12: Momentum of Objects

1. In the following table, order the objects listed below according to their momentum. Comment on the reasoning for your choices.

   Transit bus, football pass, sprinter, statue, race car, marathon runner, slapshot hockey puck, building, skateboarder

continued

Learning Activity 3.12 (continued)

Object	Amount of Momentum	Comments

continued

Learning Activity 3.12 (continued)

2. Estimate the velocity of the objects in km/h and calculate their momentum. Compare the momentum results to your order in the previous table.

Object	Mass (kg)	Velocity (km/h)	Momentum (kg • km/h)	Comments
transit bus	8000			
football pass	0.5			
sprinter	75			
Golden Boy statue	1650			
NASCAR stock car	1545			
marathon runner	65			
slapshot	0.15			
building	1 000 000			
skate-boarder	68			

Check the Learning Activity Answer Key found at the end of this module.

Impulse—The Counter and Cause of Changes in Momentum

How can you reduce an object's momentum to zero? How can you increase it? What if you want to change the direction of momentum? The answer lies in the first law of motion: to alter an object in motion, it must be acted on by an unbalanced force. There are two things you can do to alter momentum:

- Apply a force—the larger, the better.
- Increase the amount of time the force is applied.

An **impulse** is a force applied over an interval of time. Impulse is calculated with the following equation:

Impulse = Force × Time Interval

$$\vec{I} = \vec{F}(\Delta t)$$

Impulse is represented by the symbol ***I***, and is measured in newton-seconds [N•s].

Since both force and time contribute to impulse, increasing just one of these factors will still produce a strong impulse.

Example 1: Small Force, Long Time

A bicyclist squeezes her handlebar brakes, applying 20 newtons of force. She holds down the brakes for 30 seconds until she comes to a stop.

$$\vec{I} = \vec{F}(\Delta t)$$
$$\vec{I} = 20\,\text{N} \bullet 30\,\text{s}$$
$$\vec{I} = 600\,\text{Ns}$$

The bicyclist applied an impulse of 600 newton-seconds.

Example 2: Large Force, Brief Time

A tennis player hits a ball with his racquet, hammering it with 500 newtons of force for 0.1 seconds.

$$\vec{I} = \vec{F}(\Delta t)$$

$$\vec{I} = 500\,\text{N} \bullet 0.1\,\text{s}$$

$$\vec{I} = 50\,\text{Ns}$$

The racquet applied a 50 newton-seconds impulse to the tennis ball.

For more information on impulse, review page 43 of the *In Motion* booklet.

Here are some everyday examples of impulse and momentum in operation:

A. You are sliding down a hill on your toboggan with great speed but need to stop before hitting a fence. In order to decrease your momentum, you could dig your heels into the snow (applying a force) for a moment or two (time) to slow the toboggan down to a safe speed.

B. You are riding your bike to the swimming pool and will be late for your lesson if you don't hurry up. In order to increase your impulse, you need to pedal harder (more force) for the next five blocks (a longer period of time).

Learning Activity 3.13: Momentum and Impulse

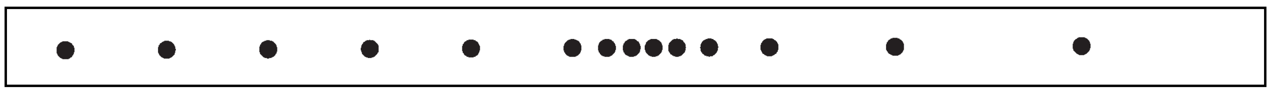
1. Impulse depends on both force and time. Give an example for each case:
   a. a large force for a short time
   b. a small force for a long time
   c. a large force for a long time
   d. a small force for a short time

continued

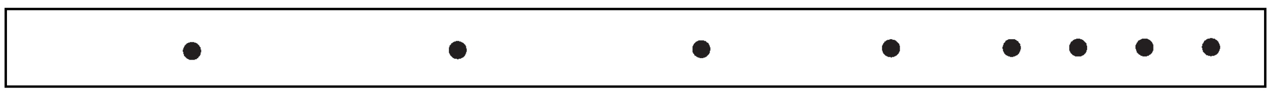
Learning Activity 3.13 (continued)

2. Two cars of equal mass are driving down Portage Avenue with equal velocities. They both come to a stop over different lengths of time. The ticker tape patterns for each car are shown on the diagram below:

Car A



Car B



   a. At what approximate location on the diagram (in terms of dots) does each car begin to experience an impulse?

   b. Which car (A or B) experiences the greatest change in momentum? Explain.

   c. Which car (A or B) experiences the greatest impulse? Explain.

Check the Learning Activity Answer Key found at the end of this module.

Summary

Momentum measures the amount of motion in an object, and is represented by the equation $\vec{p} = m\vec{v}$. Momentum can be increased or decreased by applying an impulse—a force over time, represented as $\vec{I} = \vec{F}(\Delta t)$. The relationship between impulse and momentum is extremely important for protecting passengers in car accidents. In the next lesson you will learn more about safety devices that are built to control and reduce the effects of momentum.

Notes

Assignment 3.2: The Link between Force and Motion (27 marks)

Introduction

This assignment involves a hands-on experiment with Newton's laws of motion. You are responsible for

- reading through the assignment description and familiarizing yourself with the purpose of this learning activity

- watching the video experiment, *Grade 10 Science The Link Between Force and Motion*
- filling out Tables A to D (*13 marks*)
- plotting data on Graphs B, C, and D (*12 marks*)
- answering the follow-up question (*2 marks*)

Objective

After studying the motion of many objects, Sir Isaac Newton proposed his second law of motion: "When a force acts on a mass, acceleration is produced. The greater the mass, the greater the amount of force needed to cause acceleration."

In this assignment, you will apply a constant force (gravity) to an object, and gradually increase that object's mass by adding a set of weights. **You will observe how the object's acceleration changes as its mass increases**.

Procedure

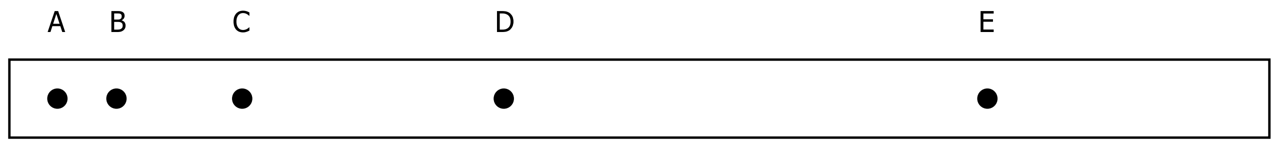
The device you will observe in this investigation is a pulley system made of three parts:

- a dynamics cart → a small, toy cart
- a suspended weight and pulley
- a tickertape timer → a motorized needle that can be set to tap a certain number of times per minute. When the needle is dipped in ink, it can mark dots on a moving piece of tickertape paper.

continued

Assignment 3.2 (continued)

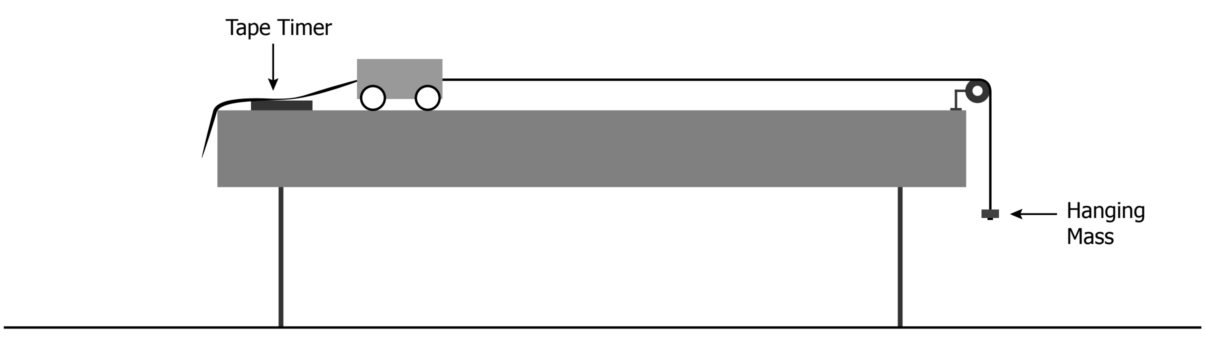
Tickertape paper looks something like this:



Does this picture look familiar? It should remind you of the moving car number lines from Lessons 4 and 5. The distance between two dots tells you how quickly the paper was moving through the tickertape timer, allowing you to calculate velocity.

The pulley system is set up as follows:

1. The dynamics cart is placed on a tall table.
2. The weight is tied to the cart's front bumper with a long piece of string. The string should be long enough for the weight to hang over the edge of the table.
3. A length of tickertape paper is taped to the rear bumper of the cart. The paper is fed through the tickertape timer, and the machine is set to tap 60 times per second.



Once the hanging mass is released, the force of gravity will pull it towards the floor, yanking the dynamics cart and the tickertape paper along for the ride. The tickertape timer will tap a series of dots on the paper 60 times per second (one dot every 1/60th of a second). Measuring the distance between dots will tell you how far the cart travelled under the influence of gravity. You can use this data to calculate the cart's velocity, and then its acceleration.

continued

Assignment 3.2 (continued)

Since the materials in this investigation are a little too technical to assemble from everyday household items, an experiment has been recorded for you on the *Grade 10 Science The Link between Force and Motion* video. Make sure you have Table A with you as you watch the video.

This investigation will be *repeated three times*, with a different mass on the dynamics cart for each attempt. After you observe all three sets of trials, you will complete the following tables and graphs, using the data from the **0 g**, **200 g**, and **400 g** masses added to the cart.

Note: It is important to recognize that the ***total combined mass*** of the dynamics cart + the falling mass (e.g., 100 g) is the mass that is being accelerated in this activity sequence. To keep things simple, though, you will label your tables and graphs with the amount of the ***mass added to the cart only***. Keep this in mind throughout the activity sequence.

Counting 60 dots on the tickertape will give you the distance travelled over 1 second. To make measurements more reasonable, you will measure the distance between every six dots. This will tell you the cart's displacement every 1/10th of a second (0.1 seconds).

Knowing the data, we can fill in the data tables for these investigations:

1. Table A: Distance between Dots and Time (no graph for Table A)
2. Table B: Position versus Time
3. Graph B: Position versus Time (for all three different masses of cart)
4. Table C: Position, Average Velocity, and Time
5. Graph C: Velocity versus Time
6. Table D: Acceleration versus Mass
7. Graph D: Acceleration versus Mass

continued

Table A: Distance between Dots and Time (Displacement) (*1 mark*)

Write down the distance between every 6 dots, as observed in the video. The first few have been done for you in **boldface**.

Time (s)	Distance between Dots (cm)		
	0 g	200 g	400 g
0.0	n/a	n/a	n/a
0.1	3.0	4.0	2.0
0.2	4.0	4.0	3.0

continued

Assignment 3.2 (continued)

Table B: Position versus Time (*3 marks*)

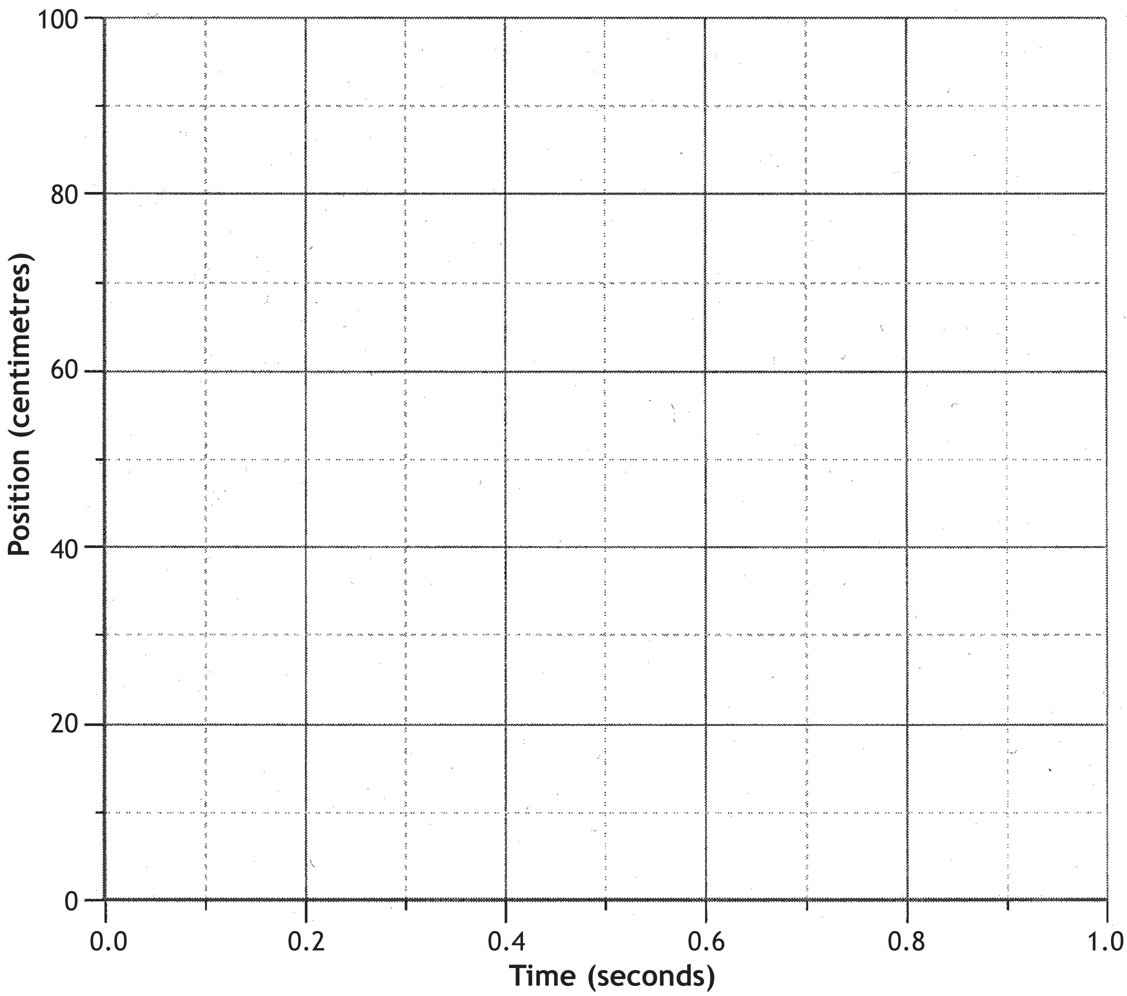
Write down the total accumulated distance that the tape travelled since 0 seconds. The first few have been done for you. Notice how the distances are added to one another.

Time (s)	Position (cm)		
	0 g	200 g	400 g
0.0	n/a	n/a	n/a
0.1	3.0	4.0	2.0
0.2	7.0	8.0	5.0

Use the data from Table B to graph Position versus Time on Graph B. Plot all three sets of data on your graph (0 g, 200 g, and 400 g). Use different-coloured dots or symbols for each plot, and label each set of points clearly. Connect each set of data with a straight line.

continued

Graph B: Position versus Time (*5 marks*)



continued

Table C: Position and Average Velocity
(*2 marks x 3 tables = 6 marks*)

There are three Average Velocity tables to be completed, one for each trial.

Transfer the "Distance between Dots" data from Table A to the "Displacement During Time Interval" column. Then, calculate the average velocity during each 0.1 second time interval. The first few calculations have been done for you. You do not need to show your calculations, just the answer. Calculate your answers to one decimal place.

0 g Mass (*2 marks*)

Time (s)	Time Interval (s)	Displacement During Time Interval (cm)	Average Velocity During Time Interval (cm/s)
0	0	-	-
0.1	0.1	3.0	30.0
0.2	0.1	4.0	40.0
0.3	0.1		
0.4	0.1		
0.5	0.1		
0.6	0.1		
0.7	0.1		

continued

Assignment 3.2 (continued)

200 g Mass (*2 marks*)

Time (s)	Time Interval (s)	Displacement During Time Interval (cm)	Average Velocity During Time Interval (cm/s)
0	0	-	-
0.1	0.1	4.0	40.0
0.2	0.1	4.0	40.0
0.3	0.1		
0.4	0.1		
0.5	0.1		
0.6	0.1		
0.7	0.1		

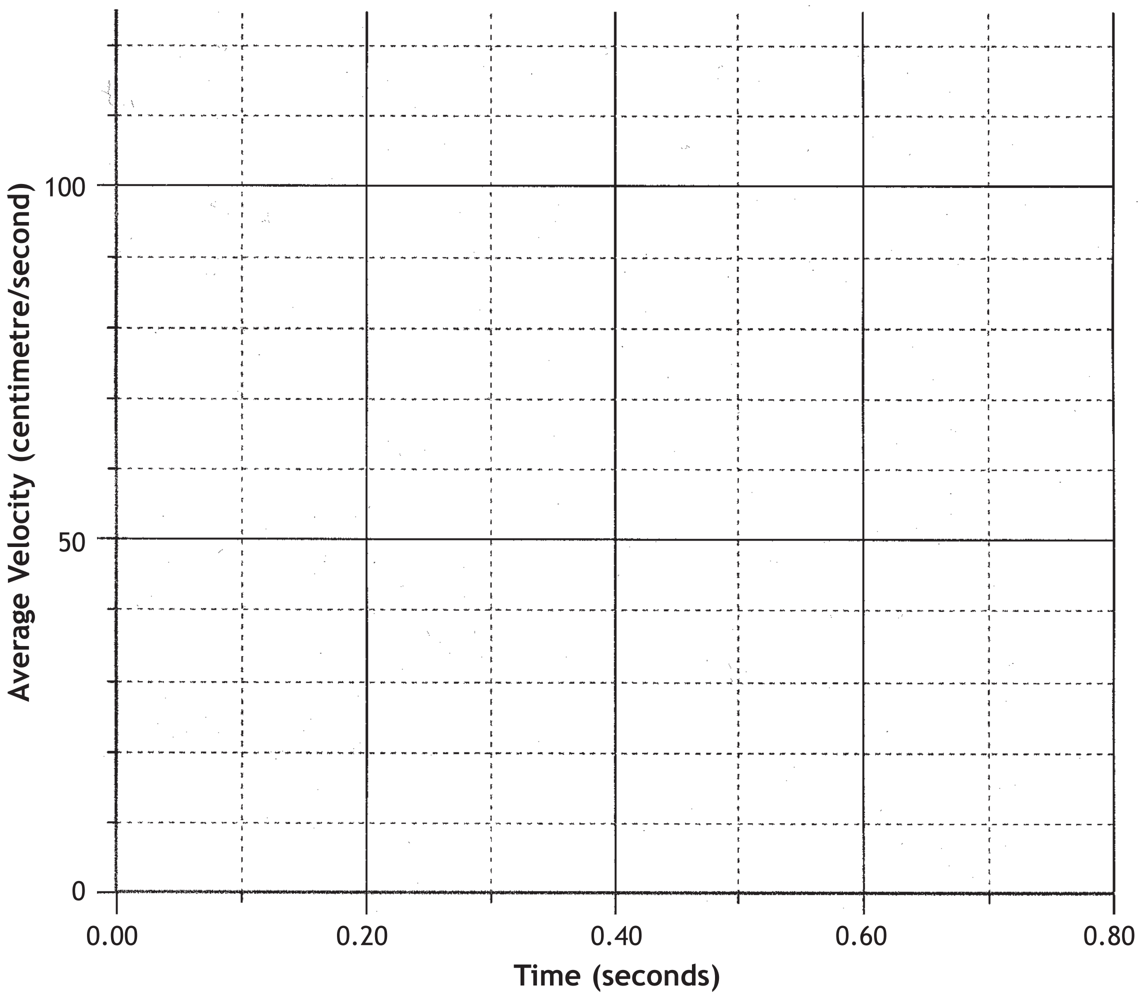
400 g Mass (*2 marks*)

Time (s)	Time Interval (s)	Displacement During Time Interval (cm)	Average Velocity During Time Interval (cm/s)
0	0	-	-
0.1	0.1	2.0	20.0
0.2	0.1	3.0	30.0
0.3	0.1		
0.4	0.1		
0.5	0.1		
0.6	0.1		
0.7	0.1		

continued

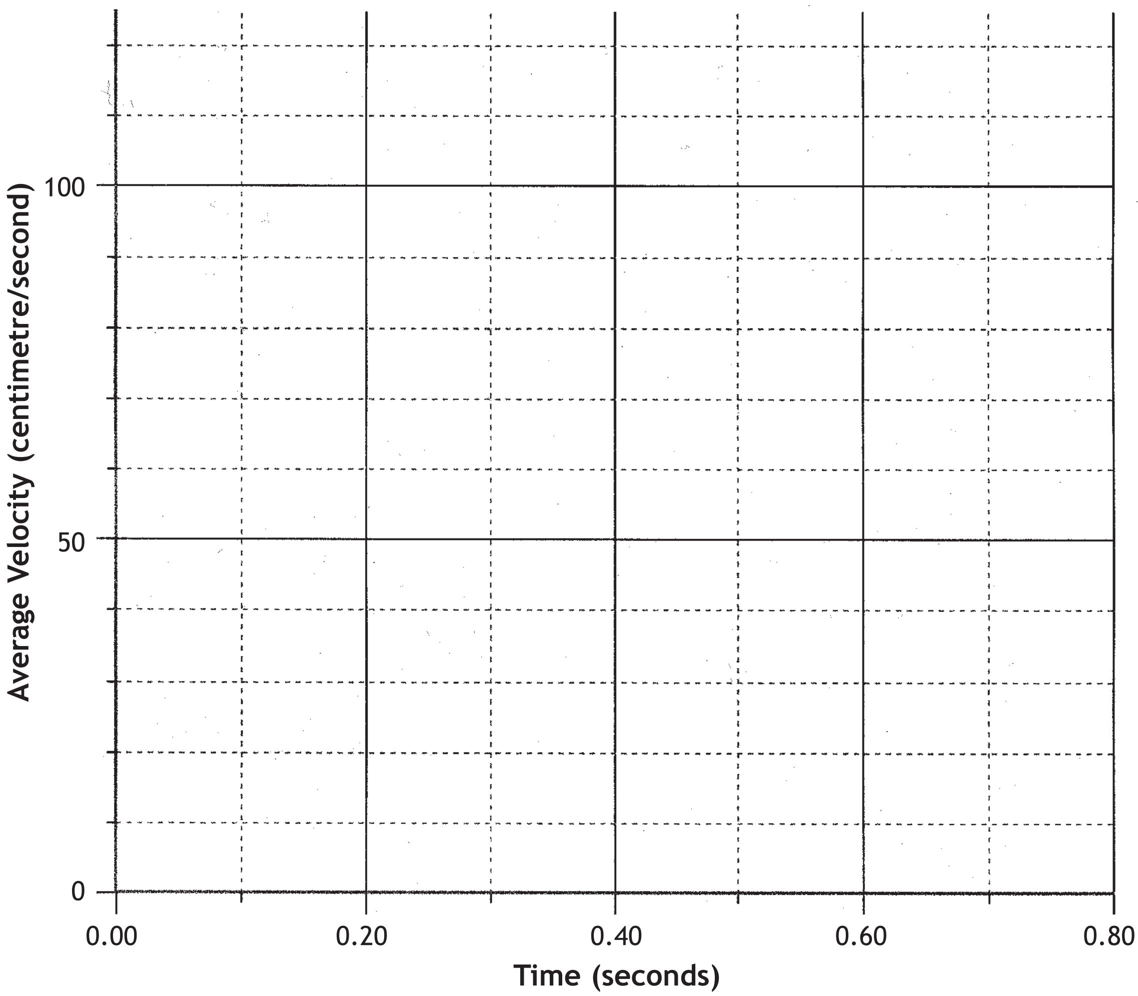
Assignment 3.2 (continued)

Graph C: Average Velocity versus Time (0 g)



continued

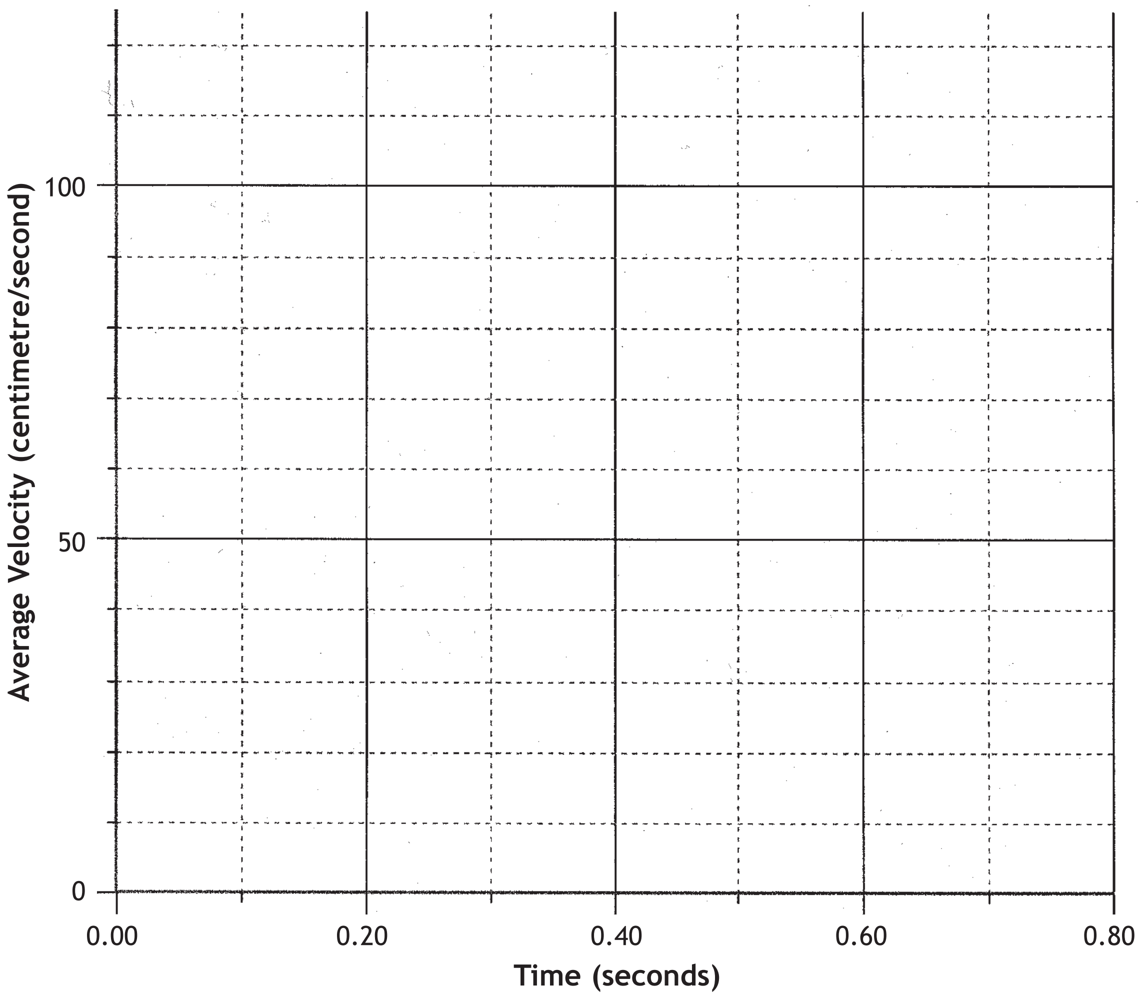
Graph C: Average Velocity versus Time (200 g)



continued

Assignment 3.2 (continued)

Graph C: Average Velocity versus Time (400 g)



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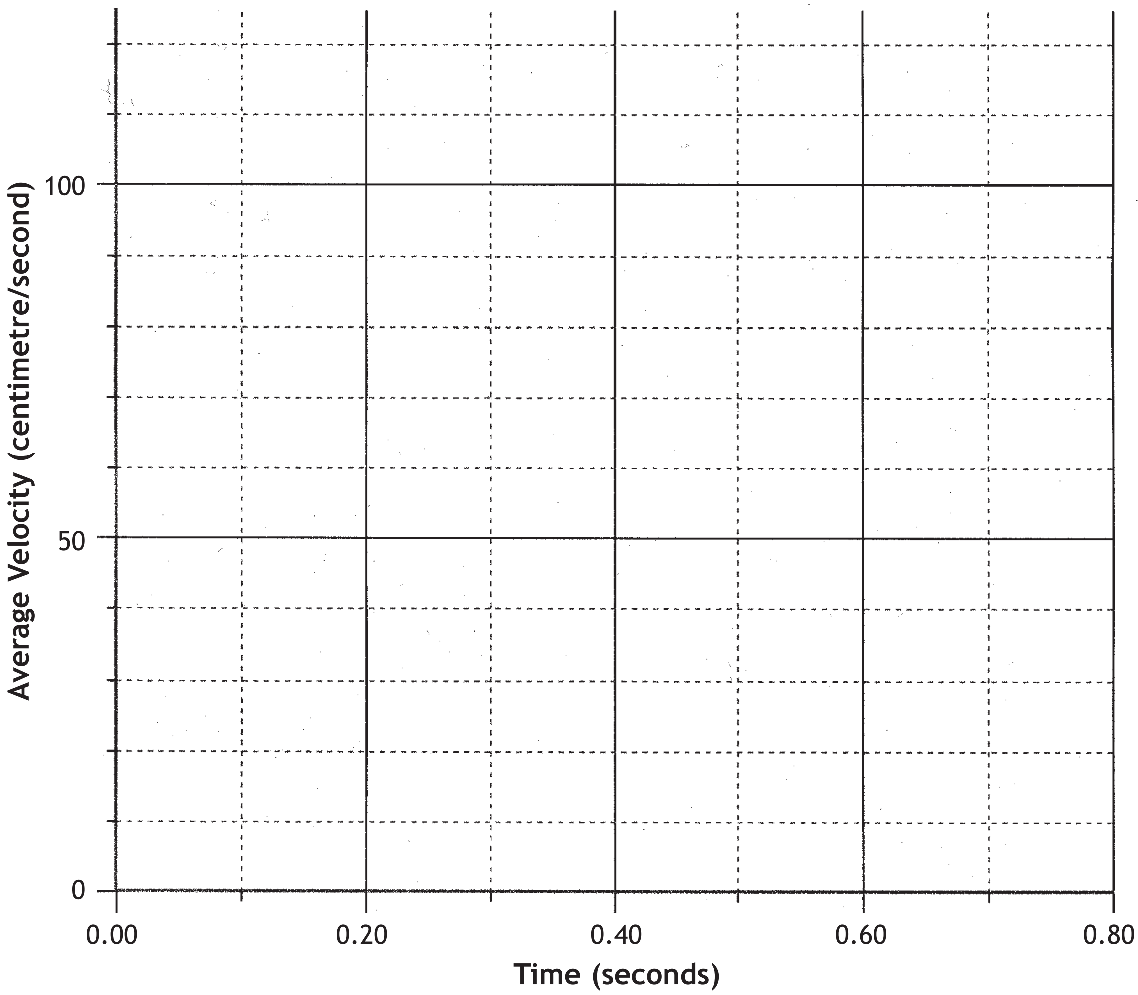
Graph C: Average Velocity versus Time (0 g, 200 g, and 400 g) (*5 marks*)



Plot the data from all **three** Table Cs on the above axis. Draw a line of best fit for each data set. Be sure to use different colours or symbols for each trial.

continued

Assignment 3.2 (continued)

Table D: Acceleration versus Mass (*3 marks*)

For each mass, calculate the average acceleration over the 0.7 second time interval.

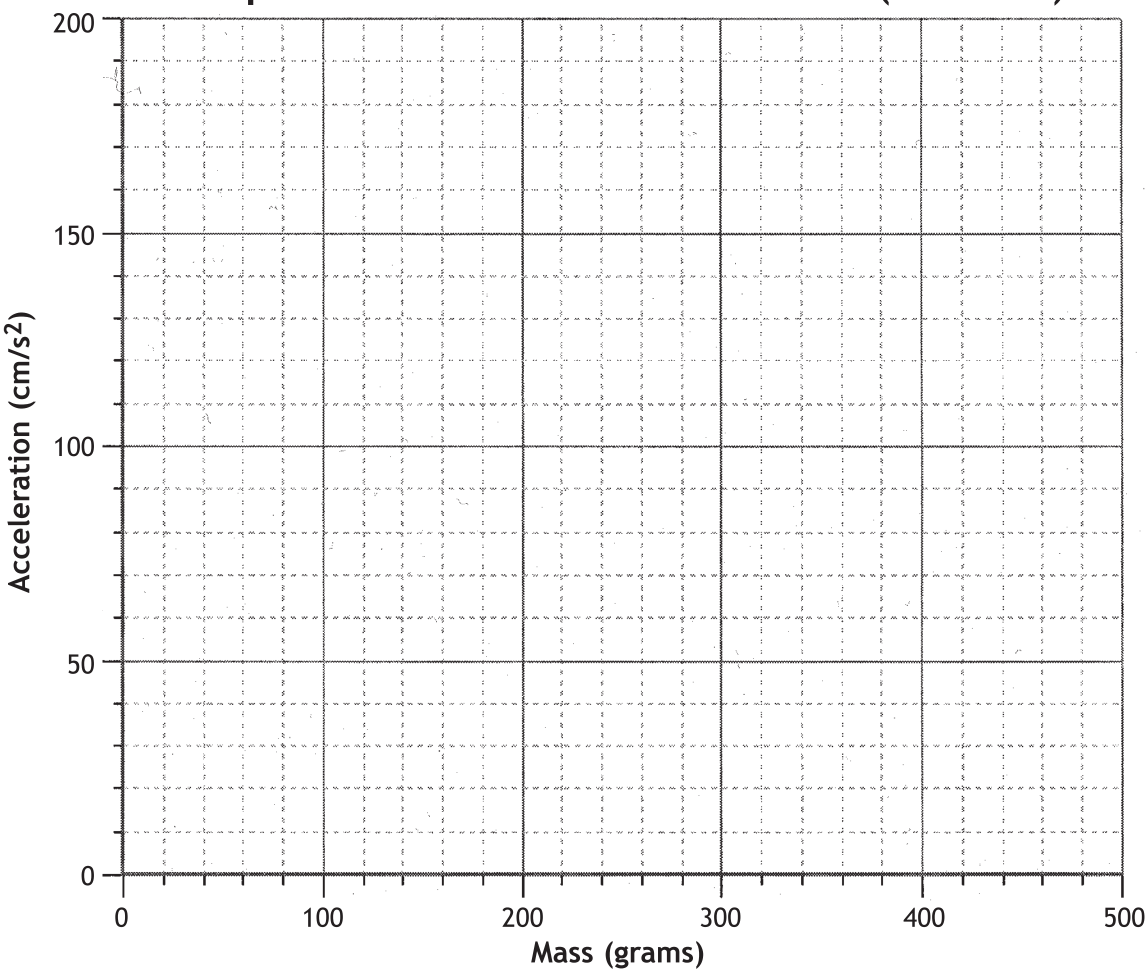
Mass (g)	Acceleration (cm/s^2)
0	
200	
400	

Graph your results, using the information from Table D.

continued

Assignment 3.2 (continued)

Graph D: Acceleration versus Mass (*2 marks*)



1. Looking at Graph D, what relationship exists between mass and acceleration? (*2 marks*)

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____

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____

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To be eligible for full marks you must submit

- completed copies of Tables A, B, C, and D (*13 marks*)
- completed copies of Graphs B, C, and D (*12 marks*)
- your answer to the follow-up question (*2 marks*)
- **Total: 27 marks**

Notes

Lesson 11: Momentum and Impulse, Part 2

Lesson Focus

After completing this lesson, you will be able to

- ❏ describe how seat belts help reduce damage to passengers by increasing impulse
- ❏ describe how air bags cushion the impact of the second collision in a car accident by increasing impulse
- ❏ give examples of other devices used to minimize force in a vehicle collision

Key Words

- seat belts
- air bags
- crumple zones
- rollover protective structures

Introduction

To safely stop a moving vehicle, its braking system applies an impulse by exerting a force on the wheels for a long period of time. In a collision, that same impulse is applied over a very short duration of time, resulting in very large, destructive forces acting on the car and its occupants. In order to cushion the blow, manufacturers have invented several devices that use the impulse-momentum relationship to decrease the force applied on cars. This lesson will introduce you to several of these safety devices.

Momentum and Collisions

In the last lesson, you learned that momentum is the product of mass and velocity. Therefore, if either mass **or** velocity increases, so does momentum. You also learned that impulse is a vector quantity and is the product of force and time. We apply a force over a period of time to change the momentum of an object, and this is impulse.

A good illustration of this concept is the egg toss. If you toss an egg on the concrete, it will crack open upon impact with the ground. A large force applied over a split second has stopped the momentum of the egg. You could also bring the egg's momentum to zero by throwing the egg into a cushion or mattress. This time the impulse is the same, but it is spread out over a longer period of time, and so the force is much less.

In Lesson 8, we discussed the notion of a first collision and a second collision. In the example of a car colliding with a building, the first collision is upon impact and involves only the car and the building. At this point, the car's momentum has been reduced to zero and the force was very great but applied over a very short period of time. Remember that the passenger of the car will continue to move forward with the same momentum that the moving car had. The second collision occurs when the passengers of that car hit the steering wheel or other object that will reduce their momentum to zero. There are many devices that are now used to help lessen the damage caused by second collisions, such as air bags and seat belts. Read pages 45 to 49 of the *In Motion* booklet for more information on "Cushioning the Blow."

Learning Activity 3.14: Safety First

1. Besides cars, what are some other machines or structures that might use crumple zones, air bags, rollover cages, or bumpers? See if you can think of one machine or structure per safety feature.

Check the Learning Activity Answer Key found at the end of this module.

Summary

Seat belts, air bags, bumpers, head restraints, crumple zones, child safety seats, and rollover protective structures (ROPS) all work as a team of cushioning devices to keep you as safe as possible in a vehicle. Now that you know more about what a collision does to the physical structure of a car, you'll go on to learn what happens to the energy in a car when it comes to a sudden and forceful stop.

Lesson 12: Conservation of Energy

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe the law of conservation of energy
- ❑ describe and identify different types of energy
- ❑ state how the law of conservation of energy applies to car crashes
- ❑ identify various conversions of energy in a car collision

Key Words

- law of conservation of energy
- kinetic energy
- heat energy
- potential energy

Introduction

Have you ever seen the aftermath of a vehicle collision? You may have noticed that parts of the car are crumpled or torn off, that glass is broken, and that fluids may be leaking from the engine. Of course, if you witnessed the actual collision, you would have heard the sounds of the two cars colliding and possibly hitting other objects as well. All these observations are examples of the law of conservation of energy at work.

Forms of Energy

The **law of conservation of energy** states that energy cannot be lost or created, but can only be transformed or converted into different forms of energy. In addition to converting energy from one form to another, energy is also transferred between objects. In a vehicle collision, energy is transferred from the car to the pavement, into specific areas of the car, and into the driver and passengers. For example, energy from the movement of the car can be transferred to the bumpers (which will crumple) or through the bones of a passenger (which may break). In a car collision, huge amounts of kinetic energy are converted and transferred to several different types of energy. These include

- **kinetic energy:** the energy of motion (e.g., wheels turning)
- **potential energy:** the energy of position with respect to the surface of Earth (e.g., an object falling from two storeys up will not fall with as much force or acceleration as an object that falls from 16 floors up)
- **heat energy:** the energy of molecules in motion (e.g., bending and breaking metals and plastics causes them to heat up; heat in brakes and tires as they try to stop the vehicle)
- **sound energy:** the disturbance of molecules (e.g., a loud crashing noise)

Energy can also be stored electrically, chemically, or in elastics and springs.

Since energy cannot be destroyed, whenever kinetic energy is reduced to zero, other forms of energy increase. For example, less motion could mean more sound and heat. After a crash has taken place, the momentum of the car is reduced to zero, which means there is no more kinetic energy. All this kinetic energy is then transferred and converted to other forms and systems. This is dangerous for passengers—especially unrestrained ones—as they then become moving objects in the car with great amounts of kinetic energy. This is where the second collision occurs and causes injury to the moving passengers.

For more details on the different types of energy, review pages 51 to 53 of the *In Motion* booklet.

Learning Activity 3.15: Conservation of Energy

1. For each of the following examples, describe the transformation of energy that has occurred:
   a. a child on a pogo stick
   b. a pole vaulter
   c. A car shoots through the intersection that you are approaching in your car. You brake hard to avoid the other car and leave skid marks on the road. You cannot avoid hitting the other car and you hear a loud crash as you collide.

Check the Learning Activity Answer Key found at the end of this module.

Summary

Energy cannot be destroyed—it is always being transferred from one form to another. Vehicle collisions are one example of how kinetic energy—moving energy—can be very quickly and violently redistributed into other forms, objects, and even people. Next lesson, you will look at a slower type of vehicle movement as you examine the influence of friction on motion.

Notes

Lesson 13: The Effects of Friction

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the effects of friction on motion
- ❑ give examples of technologies used to increase or reduce friction
- ❑ give examples of road conditions that affect friction and motion

Key Words

- friction
- surface conditions

Introduction

It is blowing snow and the roads and sidewalks are dangerously slippery. What measures can be taken to ensure safety for drivers and pedestrians? You have probably noticed trucks out sprinkling sand or salt when the streets are particularly icy. After this lesson you will be able to explain why this is done.

Surface Conditions

When you push off a skateboard, you will roll down the sidewalk quickly at first, but then slow and eventually stop. The same event will occur if you stop pedalling your bike and coast, or remove your foot from a car's gas pedal. The first law of motion tells us that a moving object will continue to move until it encounters an opposing force, so there must be a force applied against your vehicle.

One of the forces opposing motion is called **friction**. Friction occurs whenever two surfaces slide against and grip one another. The amount of friction encountered depends on

- what the surfaces are made of
- what texture the surfaces have
- the amount of force pressing the two surfaces together
- any substance that is between the surfaces (e.g., oil, glue)

Perhaps you've noticed that the rate at which your skateboard or bicycle slows down varies depending on where you ride. You might coast for a long while on smooth concrete, but on rough gravel or in gooey mud you stop more abruptly. The amount of friction you encounter depends on the surfaces that are in contact. Some surfaces stick and grip more tightly than others.

Let's return to our dilemma of the icy sidewalks. As you walk on dry pavement, the friction between your feet and the pavement allows you to walk without slipping and falling over. When the sidewalk is covered in ice, the friction is significantly reduced, so that when you push off with your feet there is less force to oppose the motion. As a result, your feet slip and you might even fall over. By sprinkling sand on the ice, we are adding some traction to the surface, so that there is once again friction between your feet and the ground. The same event applies on a street with cars: if we add sand, there will be more friction, which allows for more controlled motion.

What are some examples of conditions that can affect friction and motion on the roads?

- **Road conditions:** Icy, wet, snow-covered roads can all reduce friction; gravel and dirt roads can increase friction, unless it is very loose.
- **Weight of vehicle:** A heavier vehicle will have more friction in its tires than a lighter vehicle.
- **Type of tire:** Snow tires are made of softer rubber, and have deeper treads and maybe even metal studs to increase friction in winter conditions. Racing tires are smooth to give greater contact with dry racetracks. The drivers even heat their tires to make the rubber stickier.

Measuring Friction

The friction between two surfaces can be expressed as a decimal called the **frictional constant (*k*)**. The closer the constant is to zero, the greater the friction. Several constants are listed in the following table:

Rubber Tire on	Frictional Constant (*k*)
Dry Pavement	0.06
Wet Concrete	0.10
Snow and Ice	0.15

The frictional constant does not have a unit attached to it.

Learning Activity 3.16: Friction Factors

1. Suggest ways to reduce friction between a bicycle and the road. What could you change about your bike, and what could you change about the road?
2. Discuss why skiers and snowboarders use wax.
3. In what ways would a surface with little or no friction make driving dangerous?
4. What objects might you keep in your trunk for the winter, in the event you are stranded in the snow and need extra traction on your wheels?
5. Describe how the following conditions would affect your ability to stop a moving vehicle.
   a. a car with new tires on a dry road
   b. a car with new tires on a wet road
   c. a car with worn tires on a wet road
   d. a car with new tires on slick ice

Check the Learning Activity Answer Key found at the end of this module.

Summary

Every time you brush against a surface, you are experiencing a frictional force that opposes your motion, however slightly. This same force causes a coasting vehicle to slow down, and keeps you from flying off your feet when you walk. The strength of friction depends on the materials in contact. Smooth ice produces very little friction, which is why winter roads are covered with abrasive sand. Friction can also be expressed as a numerical constant. In a future lesson, you will apply these constants to determine just how friction helps (or hinders) a braking car.

Lesson 14: Braking Distance

Lesson Focus

After completing this lesson, you will be able to

- ❑ list and explain factors that affect braking distance

Key Words

- reaction time
- speed
- braking distance

Introduction

You are driving to your soccer practice when you notice a person crossing just ahead. How much distance will you need to stop and avoid hitting the pedestrian? How much time will it take to stop your car? In this lesson you will learn about the factors affecting the time and distance it takes for you to bring your car to a complete stop.

Stopping a Car

You have already learned that friction is the force that opposes motion. When applying the brakes in your car, there is friction created between the brake pads and the rotating wheel, which causes the car to slow down and eventually stop. From the time you apply the brakes to the time you come to a complete stop, the car continues to move. The distance you cover while braking is called the **braking** or **stopping distance**.

A person's **reaction time** also has an impact on braking distance. Reaction time is the amount of time it takes for you to recognize a situation and react to it. For example, if you see a dog run out in front of your car, you process this information and decide that you need to immediately apply the brakes. It might take you two seconds to react to the dog on the street and apply the brakes: this would be your reaction time. Some people naturally have quick reaction times, but there are some factors that will increase your reaction time and should be avoided when driving. These factors include the following:

- **Alcohol:** Alcohol is a depressant and will slow down your reaction time.
- **Hallucinogenic drugs:** These drugs inhibit transmitters for the nervous system and will slow down your reaction time.
- **Depressant drugs:** These drugs slow down your body activity, including reaction time.
- **Driver fatigue:** The more tired you are, the slower you will process information and respond to it.
- **Cold/allergy medications:** Many over-the-counter medications for the relief of cold, flu, and allergy symptoms contain active ingredients that can affect reaction time. Some antihistamines, for instance, produce drowsiness.

Even if you have a fast reaction time and are wide awake, sometimes braking distance can be longer than you anticipated. There are factors that can influence stopping distance that are out of your control. When driving conditions are slippery, wet, or snow-covered, friction is reduced and braking time will be increased. While you cannot control the road conditions, you must anticipate a longer braking distance and drive accordingly. This means slowing down and giving yourself plenty of room to stop.

Finally, there are factors that affect braking distance that have to do with the condition of your vehicle. Are your brakes in good working order? If your brakes are wearing out, then your stopping distance will be increased. You must also consider your tires. Do you have enough tread left on your tires to give you traction when braking? If your tires are worn out and are getting “bald,” then your stopping distance will be increased.

Learning Activity 3.17: Braking Factors

1. Describe the relationship between reaction time and braking distance.
2. Explain why drinking and driving don't mix.
3. Identify substances that, when ingested, will have a negative effect (by slowing you down) on reaction time.
4. Discuss why braking distance on a gravel road is greater than that on a paved road.
5. When driving, what factors should you assess in order to prepare yourself for the required braking distance?

Check the Learning Activity Answer Key found at the end of this module.

Summary

Factors that affect braking distance include the driver's reaction time, the road conditions, and the condition of the vehicle.

Notes

Lesson 15: The Mathematical Relationship between Speed and Braking Distance

Lesson Focus

After completing this lesson, you will be able to

- ❑ describe the mathematical relationship between velocity and braking distance
- ❑ define, and use examples of, the frictional constant
- ❑ compare the braking distance for vehicles of varying mass and under various surface conditions

Key Words

- frictional constant
- braking distance

Introduction

If you are running on ice and need to stop suddenly, are you able to? What about if you are running on dry cement? You may have noticed that surfaces that offer more friction make it easier to stop. Likewise, surfaces with less friction make it more difficult to stop suddenly. Why is this?

Braking Distance

You have already investigated how the speed of a moving car affects the total distance it requires to completely stop. The faster you move, the longer that distance becomes. The mathematical relationship between speed and braking distance is the following:

$$d \propto v^2$$

This means that as you **double your speed**, the braking distance increases by ***four times***. This equation is read as "braking distance is proportional to the square of the speed."

Braking distance is also affected by the **condition and type of driving surface**. When there is more friction between the tires and the surface, then braking distance is less (e.g., dry pavement). If there is very little friction, then more braking distance is required (e.g., ice). We can use the **frictional constant**, ***k***, to indicate how much friction exists for a given surface. The closer the number is to zero, the more friction there is.

Physicists account for the effects of friction by using a mathematical constant for different kinds of surfaces. This constant is symbolized by the letter *k*.

Rubber Tire against:	Frictional constant *k* (when velocity is in m/s)
Dry Pavement	0.06
Wet Concrete	0.10
Snow and Ice	0.15

When two surfaces produce a large amount of friction, the frictional constant will have a low value. Two surfaces that slip against each other have high values for *k*.

The frictional constant is the final piece of data needed to calculate braking distance. When you account for friction, braking distance can be found as

$$d = kv^2$$

braking distance = frictional constant × speed²

As an example, find the braking distance for a car driving on dry pavement when its speed is 50 km/h.

First, you must convert the speed into metres-per-second, since the frictional constant is calibrated for these units.

$$50 \text{ km/h} \times 1000 \text{ m/km} \times 1 \text{ h}/3600 \text{ s} = 13.9 \text{ m/s}$$

Next, apply the k value for dry pavement, listed in the previous chart.

$$d = kv^2$$

$$d = 0.06 \times (13.9)^2$$

$$\mathbf{d = 11.6 \text{ m}}$$

Learning Activity 3.18: Calculating Braking Distance

1. You are driving on a side road that is not paved. There is a sign that indicates the frictional constant of the surface is 0.12. How does this information help you drive safely?
2. What would be the required stopping distance for a car travelling at 100 km/h on an ice road in northern Manitoba? (You will have to convert km/h into m/s by multiplying by a conversion factor—km/h ÷ 3.6 = m/s.)
3. Calculate and then compare the braking distances for a car travelling at 30 km/h and a car travelling at 90 km/h on a wet concrete street. What do you conclude?

Check the Learning Activity Answer Key found at the end of this module.

Summary

By multiplying the square of speed with the frictional constant for the appropriate surface, you can find the exact distance required to bring a vehicle to a full stop. However, before you can apply the brake pedal, your brain must first recognize a need to stop, and send a signal to your limbs. The next lesson will cover the relation between reaction time and braking distance.

Notes

Lesson Focus

After completing this lesson, you will be able to

- ❑ calculate the distance a car travels for a given reaction time
- ❑ calculate total stopping distance

Key Words

- reaction time
- total stopping distance

Introduction

You are driving to school one morning after a long night of studying. As you drive, you are trying to remember as many details as possible. You snap back to reality and see a school bus ahead in the school zone. You know you must stop before the school bus, as there will be children getting off the bus any moment and crossing the road. How much distance does the car travel while you process what is going on and start to brake? Will you be able to stop in time? Does the fact that you are tired and distracted affect your reaction time and total stopping distance? The answers to these questions and more are in this lesson.

Total Stopping Distance

The last few lessons and activities have allowed you to investigate the relationship between speed and braking distance, and the influence that road conditions and driver alertness have on braking distance. These calculations for braking distance do not take into account the **reaction time** of the driver. In order to give an accurate idea of actual braking time, we must add the distance the vehicle travels while the driver reacts.

Reaction Time Example

Let's say a driver takes 4.0 seconds to react to an icy patch on the road before he or she uses the brakes to bring the car to a stop. If the car is travelling at 55 km/h, we can calculate the distance the car will travel by using our understanding of speed.

If speed is calculated by dividing distance by time, then we could isolate distance this way:

Speed = distance/time

Distance = speed × time

Because we have a time period in seconds, we need to convert km/h to m/s by dividing by 3.6.

55 km/h / 3.6 = 15.3 m/s

Now put in our known values into our distance formula:

Distance = (15.3 m/s)(4.0 s) = 61 m

If there was a person only 50 metres away, then there would not be sufficient time to stop the car and avoid hitting that person. However, to accurately get a picture of total stopping distance, we must add this distance **plus** the distance necessary to brake. The braking distance can be calculated using the equation $d = kv^2$.

Therefore,

Total Stopping Distance =

Reaction Distance + Braking Distance

Total Stopping Distance Example

Let's look at an example of total stopping distance. Say a car is travelling at 50 km/h on dry pavement when a dog runs across the road, 34 m ahead. If the driver's reaction time is 1.5 s, will he be able to stop his car in time to avoid hitting the dog?

First, identify your known values. Convert km/h to m/s.

$k_{\text{dry concrete}}$ = 0.06 (from the table on page 107)
v = 50 km/h / 3.6 = 13.9 m/s

Second, fill in the known values into our braking distance formula.

$$d_{brake} = kv^2$$

$$d_{brake} = (0.06)(13.9)^2$$

$$\mathbf{d_{brake} = 11.6\ m}$$

Next, find the reaction (rxn) distance.

$$d_{rxn} = \text{speed} \times \text{time}$$

$$d_{rxn} = 13.9\ \text{m/s} \times 1.5\ \text{s}$$

$$\mathbf{d_{rxn} = 20.9\ m}$$

Now you can find the total stopping distance.

$$d_{stop} = d_{brake} + d_{rxn}$$

$$d_{stop} = 11.6\ \text{m} + 20.9\ \text{m}$$

$$\mathbf{d_{stop} = 32.5\ m}$$

The driver's total stopping distance was 33 m (rounded). The dog just barely made it.

To learn more about the factors that affect a driver's reaction time—and to learn how to measure your own reaction time—review pages 58 to 59 of the *In Motion* booklet.

Learning Activity 3.19: Stop for a Minute

1. Calculate the total stopping distance for a car that is travelling at 60 m/s on a rain-soaked road (use 1.5 seconds as the driver's reaction time).
2. The light turns yellow at the upcoming intersection, which is 85 metres away. You are travelling at 60 km/h on dry pavement. Will you be able to stop before the light turns red?
3. a. The average reaction time for a healthy, alert person is 1.5 seconds. How would a delayed reaction time affect your total stopping time?

   b. What factors might cause your reaction time to be delayed?

continued

Learning Activity 3.19 (continued)

4. A pedestrian wearing dark clothing at night is only visible at a distance of about 35 m to a driver using low beams. Calculate the maximum speed at which a car could travel so that a driver could brake and avoid a collision (assume a 1.5 second reaction time and dry pavement).
5. Some driver education experts recommend that "when the vehicle ahead of you passes a certain point, such as a sign, count 'one-thousand-one, one-thousand-two, one-thousand-three.' This takes about 3 seconds. If you pass this same point before you finish counting, you are following too closely." They also suggest a "4 second or more cushion" in inclement weather. Using the laws of physics and your understanding of braking distance, write a rationale for this rule.

Check the Learning Activity Answer Key found at the end of this module.

Summary

When you are running, it is easy enough to bring your body to a stop. With vehicles such as bicycles and cars that allow you to travel at much faster speeds, it takes a longer time to slow yourself to a complete halt, during which you will still be moving. Your personal reaction time, the condition of the road, the wear on your brakes, even weather can influence how long it takes for you to stop. It's worthwhile to give yourself that extra little space when on the road, and that extra time in your schedule so you don't feel the need to rush to a destination.

Lesson Focus

After completing this lesson, you will be able to

- ❑ use a decision-making process to address an issue related to safe driving practices
- ❑ decide how speed and disobeying conditions of your licence relate to probability of accidents
- ❑ decide how accidents affect several groups of individuals

Introduction

In this final lesson you will look at a decision-making model and examine the decisions that lead to a serious traffic accident.

Making Decisions

A decision-making process can be used to make any informed, responsible decision. The following example outlines the steps of this process.

Step 1: Identify the issue and raise a question.

Example: Should you get your driver's licence?

Step 2: Research the implications of your decision.

What are the positive and negative effects of this decision?

Examples:

- I may have more freedom. (positive)
- Gas and parking will cost me money. (negative)

Step 3: Evaluate your research and develop possible courses of action.

Example: You decide you do want your licence. Your choices are to go ahead and get your learner's permit or to first enrol in a local driver training course.

Step 4: Carefully make your decision and develop an action plan.	
Example:	You decide to take a driver training course first. You call several driving schools and book your session.

Step 5: Reflect on your decision and the process you used.	
Example:	Did you consider all the options? Are you happy with the decision? What could you have done differently?

Can you see how the same process can be used for decisions about safety?

Learning Activity 3.20: Collision Scenario

Read the article "Lebanon Teen-ager Dies of Injuries Suffered in Car Crash," located on page 64 of the *In Motion* booklet. Answer the following questions, using the decision-making model as a guide.

1. What different choices could the teens have made to possibly avoid this tragedy?
2. Who are all the people affected in this scenario? In what ways are these people affected?
3. Why do you think the state of Oregon requires that new drivers cannot give rides to people outside of their family for the first 90 days they have their licence? What kind of distractions may cause potential problems, especially for new drivers?

Check the Learning Activity Answer Key found at the end of this module.

Summary

A five-step decision-making process can lead to safe driving practices.

Assignment 3.3: Speed and Braking Distance (15 marks)

Introduction

In this activity you will be studying the effects of speed on braking distance. You are responsible for

- reading through the assignment description and familiarizing yourself with the purpose of this activity
- watching the video experiment on the *Grade 10 Science Speed and Braking Distance* video
- filling out Table A (*5 marks*)
- plotting data on Graph A (*6 marks*)
- answering the follow-up questions (*4 marks*)

Objective

In this investigation you will simulate the braking of a moving vehicle by sending a toy car down a ramp, and having it run into a paper slider that will gradually reduce its speed. You will release your car from 5 different points on the ramp, each one proportionally increasing the speed.

You have the option of setting up your own experimental apparatus (you can use the same inclined plane you used in Assignment 3.1), or watching the *Grade 10 Science Speed and Braking Distance* video.

What You Need

- an inclined plane (a long, flat surface that can be raised on an angle)
- a piece of paper (10 cm x 12 cm)
- a metric ruler
- a toy car
- masking tape

continued

Procedure

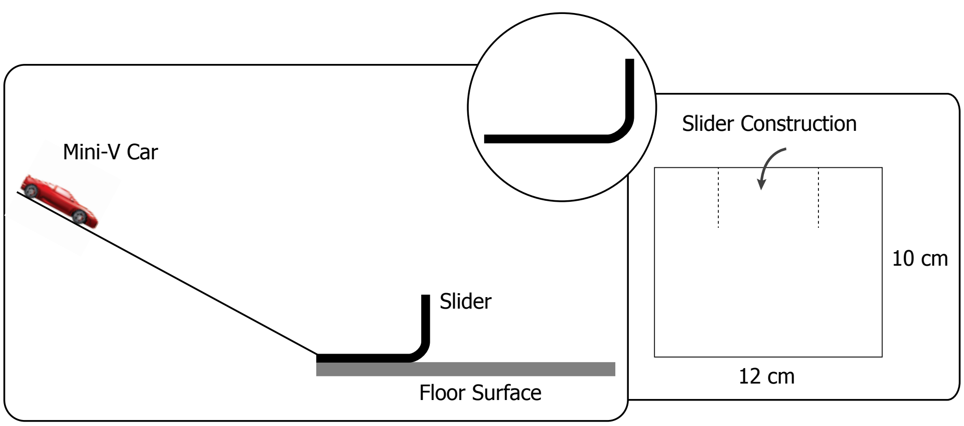
Part I: Calibration

First, you must set up your inclined plane so you can release the toy car with double and triple its original speed.

1. Set up your inclined plane at the edge of a tall table. On the floor, use the masking tape to mark the point 12 cm from the edge of the table.
2. Release the toy car down the inclined plane so that it lands (or first bounces) on the 12 cm mark on the floor. Once you succeed, use the masking tape to mark the release point on the plane that provided the 12 cm landing.
3. Repeat steps 1 and 2 until you find the release points on the plane that allow for 24 cm, 36 cm, 48 cm and 60 cm landings. (2x, 3x, 4x, and 5x the original distance).

Part II: Experimentation

1. Without changing the angle of your inclined plane, move it to the floor. There should be plenty of flat, open space in front of it for your car to roll on.
2. Fold your piece of paper into quarters, and then bend it into an L-shape to form a slider.



3. Release the car from point #1 on the inclined plane (the closest point to the bottom of the ramp). The slider should be positioned at the bottom of the ramp so that the car will slide into the paper brake and slow down.

continued

Assignment 3.3 (continued)

4. Measure the distance the car travelled from the bottom of the ramp to the point where the car came to a stop.
5. Repeat two more times and record braking distance for each trial (three trials at each point will provide more accurate results).
6. Calculate the average braking distance for the car released from point #1.

   Repeat steps 1–4 for points 2, 3, 4, and 5 on your ramp. Remember to complete three trials at each point and then calculate the average. Record your findings in Table A below. (*5 marks*)

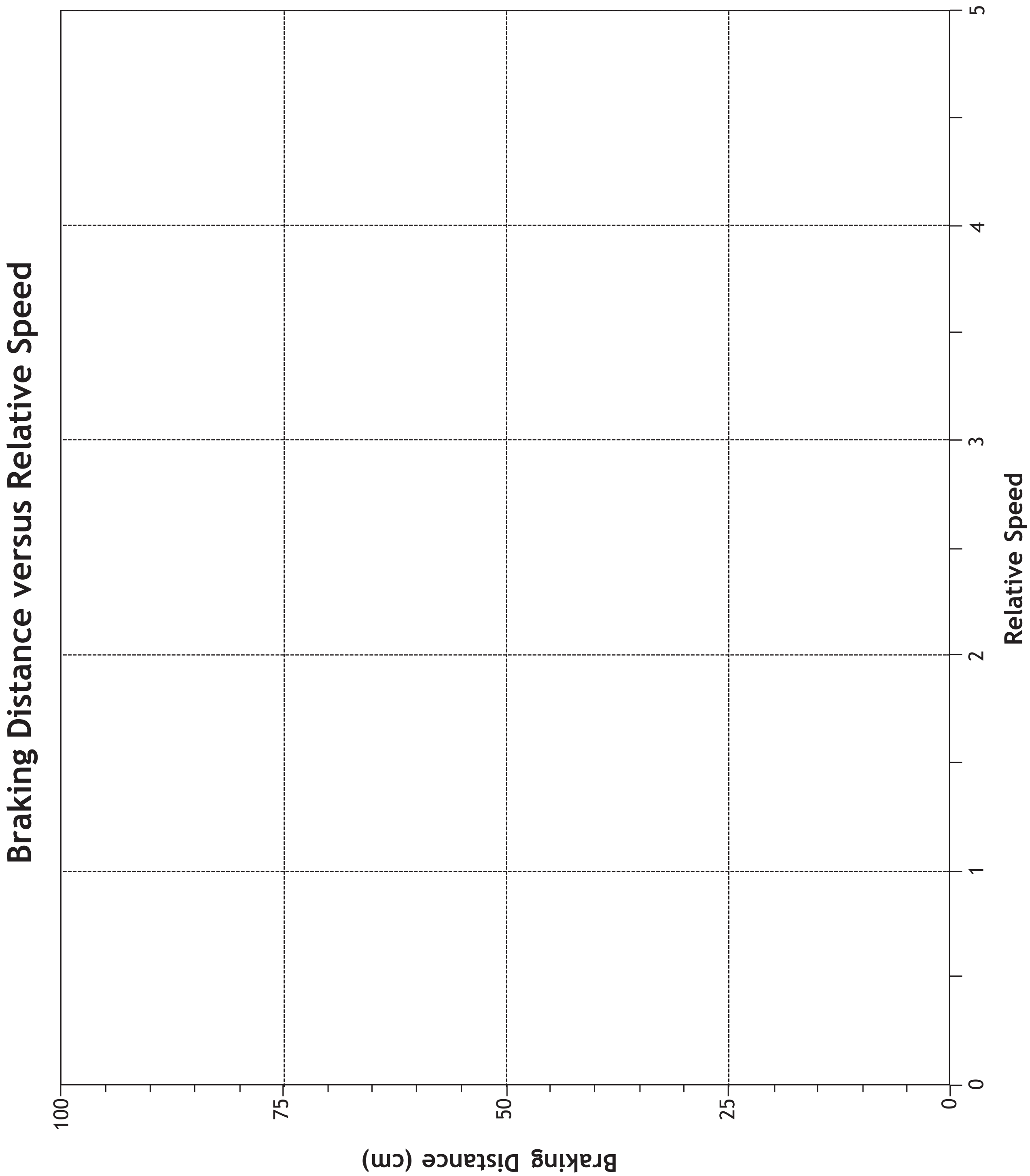
Table A

Relative Speed	Trial #1	Trial #2	Trial #3	Average (cm)	Comments
1					
2					
3					
4					
5					

7. Now you can graph the results from Table A. The graph will be Braking Distance versus Relative Speed. A blank graph is provided on the following page. (*6 marks*)

As in Assignment 3.1, you do not have to calculate the exact speed. If your inclined plane was properly calibrated, then as you move from one release point to the next, the toy car's speed will double, triple, and so on.

continued


Braking Distance versus Relative Speed
Relative Speed
0
1
2
3
4
5
Braking Distance (cm)
0
25
50
75
100

continued

Assignment 3.3 (continued)

Follow-up Questions

1. Describe the shape of your graph. Looking over your results, what can you conclude about the relationship between braking distance and speed? (*2 marks*)

2. Using your results, what advice could you offer to drivers who have a tendency to speed? (*2 marks*)

To be eligible for full marks you must submit

- a completed copy of Table A (*5 marks*)
- a completed copy of the Braking Distance versus Relative Speed Graph (*6 marks*)
- your answer to the follow-up questions (*4 marks*)
- **Total: 15 marks**

Notes

Submitting Your Assignments

It is now time for you to submit Assignments 3.1 to 3.3 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.

- ❑ Assignment 3.1: Inertia and the Unrestrained Passenger
- ❑ Assignment 3.2: The Link between Force and Motion
- ❑ Assignment 3.3: Speed and Braking Distance

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

Notes

Module 3

Learning Activity Answer Key

Module 3
Learning Activity Answer Key

Lesson 1

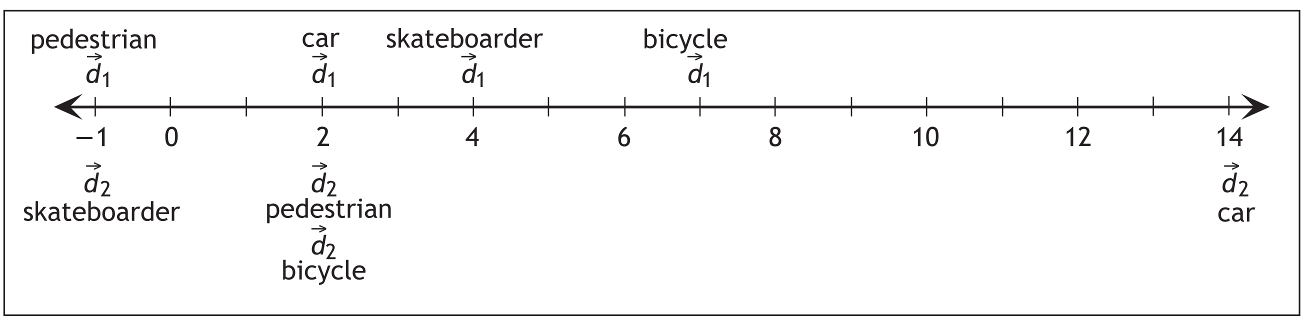
Learning Activity 3.1: Distance and Displacement

1. The following data represents the initial (d_1) and final (d_2) positions of a car, bicycle, pedestrian, and skateboarder. All positions are measured with reference to origin point "0."

	Car	Bicycle	Pedestrian	Skateboarder
$\vec{d}_1$	+2 m	+7 m	–1 m	+4 m
$\vec{d}_2$	+14 m	+2 m	+2 m	–1 m

a. Draw a number line and label an origin as point "0." Mark the initial position of each object above the line.

b. Mark the final position of each object below the line.



c. Calculate the displacement of each object.

Displacement = final position – initial position

$$\Delta\vec{d} = \vec{d}_2 - \vec{d}_1$$

For the car, $\Delta\vec{d}$ = +14 m – (+2 m) = +12 m
For the bicycle, $\Delta\vec{d}$ = +2 m – (+7 m) = –5 m
For the pedestrian, $\Delta\vec{d}$ = +2 m – (–1 m) = +3 m
For the skateboarder, $\Delta\vec{d}$ = –1 m – (+4 m) = –5 m

d. Assuming that each displacement takes place in the same period of time, describe the motion of each vehicle and pedestrian. In what direction are they travelling, and how far? Which is moving the fastest? Which is the slowest?

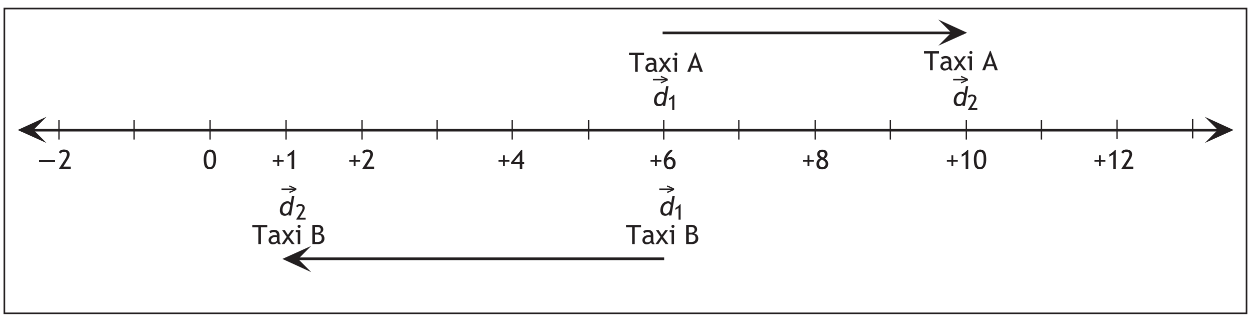
The car travelled a distance of 12 m to the right. The bicycle travelled 5 m to the left. The pedestrian travelled 3 m to the right. The skateboarder travelled 5 m to the left also.

The bicycle and the skateboarder travelled at the same rate and kept the same distance apart. The car passed by the skateboarder first, then the bicycle. The pedestrian passed the skateboarder and ended up at the same position as the bicycle.

The car was travelling the fastest. The pedestrian was travelling the slowest. The bicycle and the skateboarder travelled at the same speed in the same direction.

2. Two taxis are travelling along Pembina Highway in opposite directions. Taxi A changes its position from +6 to +10 during the same time as Taxi B moves from +6 to +1.

a. Draw a diagram to show the initial and final positions of each taxi.



b. Calculate the displacements of each taxi.

Taxi A $\vec{d}_1 = +6$ **and** $\vec{d}_2 = +10$

$\Delta\vec{d} = \vec{d}_2 - \vec{d}_1$

$+10-(+6) = +4$

Taxi B $\vec{d}_1 = +6$ **and** $\vec{d}_2 = +1$

$\Delta\vec{d} = \vec{d}_2 - \vec{d}_1$

$+1-(+6) = -5$

c. Describe the movement and speed of both taxis. Which vehicle is moving faster?

The displacement of Taxi A is +4 and the displacement of Taxi B is –5. Since the time of travel for both taxis was the same, the taxi that travelled farther had the higher speed. Taxi B was the faster moving vehicle.

3. A truck driver travelling on the Trans-Canada highway gets a flat tire and radios for help. She reports her current position as on the Trans-Canada highway 7 km from Brandon.

   a. What information is missing from the driver's report?

   The truck driver reported her distance from Brandon, but she did not report the direction in which she had been travelling. She could be 7 km east or west of Brandon.

   b. A roadside assistance vehicle is currently located 10 km east of Brandon (+10 km). Use a number line to determine how far the vehicle would need to travel in order to reach the truck (at all possible positions).

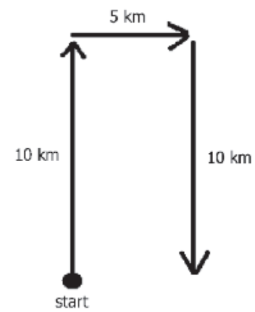
R = rescue vehicle
T = truck

If 7 km east of Brandon, $\Delta\vec{d}$ = 7 km – 10 km = –3 km

If 7 km west of Brandon, $\Delta\vec{d}$ = –7 km – 10 km = –17 km

If the truck driver is 7 km east of Brandon, the rescue vehicle must travel 3 km west (-3 km). If the truck driver is 7 km west of Brandon, the rescue vehicle must travel 17 km west (-17 km).

4. Jack is searching for a buried treasure. From his current position, his map tells him to move 10.0 km north through an alligator-infested swamp, 5.0 km east through a scorching-hot desert, and then 10.0 km south through a field of poison oak.
   a. Draw a diagram of the route Jack must take according to the map. Label all distances.



   b. What is the total distance Jack must travel according to these directions?

      Jack must travel 25.0 km according to the map's directions.

   c. How far will Jack displace himself from his initial position after following the map's directions?

      $\Delta\vec{d} = d_2 - d_1$

      $\Delta\vec{d} = 5.0 \text{ km east} - 0 \text{ km} = 5.0 \text{ km east}$

      Jack will displace himself 5.0 km to the east.

   d. What would be the easiest way for Jack to reach the treasure?

      The easiest way for Jack to reach the treasure would be to walk 5 kilometres to the east.

5. How are distance and displacement similar? How are they different?

   Distance and displacement both measure changes in position. Distance measures your total movement between a starting point and an end point. Displacement measures your net movement between a starting point and an end point. Distance measures movement in all directions, while displacement measures movement in a specific direction.

Lesson 2

Learning Activity 3.2: Time Management

1. When would it be useful to track time in intervals, and when would you need to track an instant of time? Provide an example of each.

   Interval of time—**the time it takes to get from point A to point B; the time it takes to complete a task; the amount of time you wait in line**

   Instant of time—**the time at a specific moment during the day, such as the time you were born; the time that school starts; the time that lunch ends**

2. Identify from the following list examples that are intervals of time and those that are instants of time.

   a. A flight from Winnipeg to Toronto takes 1 hour and 51 minutes.

   interval: **the difference in time from point A to point B**

   b. The train arrives at 1:13 p.m.

   instant: **this example relates to a specific moment in time**

   c. The next bus should come at 8:20 a.m.

   instant: **this example also relates to a specific moment in time**

   d. A phone conversation begins at 7:00 p.m. and ends 20 minutes later.

   interval: **the duration of the phone call is an interval, not a specific moment**

Learning Activity 3.3: Scalar or Vector?

1. Explain the difference between a scalar quantity and a vector quantity.

   A scalar quantity is only a magnitude, which is to say that there is only a numerical value. A vector quantity has a magnitude and a direction given together.

2. For each quantity, give the symbol and unit and state whether it is a vector or scalar quantity.

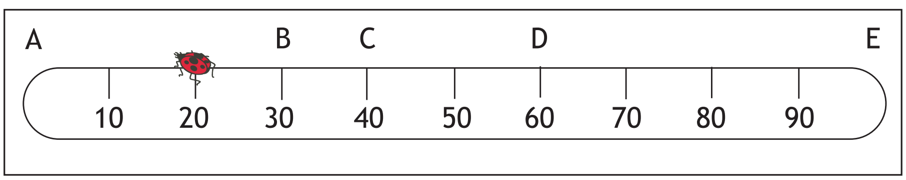
Quantity	Symbol of the Quantity	Unit	Vector or Scalar
time instant	t	second (s)	scalar
time interval	Δt	second (s)	scalar
distance travelled	Δd	metre (m)	scalar
displacement	$\Delta \vec{d}$	metre (m)	vector
mass	m	kilogram (kg)	scalar
length	l	metre (m)	scalar
speed	v	metres/second (m/s)	scalar
velocity	$\vec{v}$	metres/second (m/s)	vector
force	$\vec{F}$	newtons (N)	vector

LESSON 3

Learning Activity 3.4: Velocity of an Object in Motion

1. For each set of variables, find the missing information and fill in the blank spaces in the table. Use a "+" sign to indicate forward movement and a "–" sign to indicate backward movement.

Velocity of an Object in Motion		
Change in Position (cm)	**Change in Time (s)**	**Velocity (cm/s)**
–20 cm	5 s	**–4 cm/s**
+676 cm	13 s	+52 cm/s
+50 cm	**10 s**	+5 cm/s
–120 cm	10 s	**–12 cm/s**
–225 cm	75 s	–3 cm/s



2. A somewhat confused ladybug is moving back and forth along a metre stick. Determine both the displacement and distance travelled by the ladybug as it moves between the following points:

   a. A to B

$$\Delta\vec{d} = \Delta\vec{d}_2 - \vec{d}_1 = +30 \text{ cm} - 0 \text{ cm} = +30 \text{ cm}$$
$$\Delta d = 30 \text{ cm}$$

   b. C to B

$$\Delta\vec{d} = \Delta\vec{d}_2 - \vec{d}_1 = +30 \text{ cm} - (+40 \text{ cm}) = -10 \text{ cm}$$
$$\Delta d = 10 \text{ cm}$$

c. C to D

$$\Delta\vec{d} = \Delta\vec{d}_2 - \vec{d}_1 = +60 \text{ cm} - (+40 \text{ cm}) = +20 \text{ cm}$$
$$\Delta d = 20 \text{ cm}$$

d. C to E and then to D

$$\Delta\vec{d} = \Delta\vec{d}_2 - \vec{d}_1 = +60 \text{ cm} - (+40 \text{ cm}) = +20 \text{ cm}$$
$$\Delta d_{CE} = 60 \text{ cm};\ \Delta d_{ED} = 40 \text{ cm};\ \Delta d_{TOTAL} = 100 \text{ cm}$$

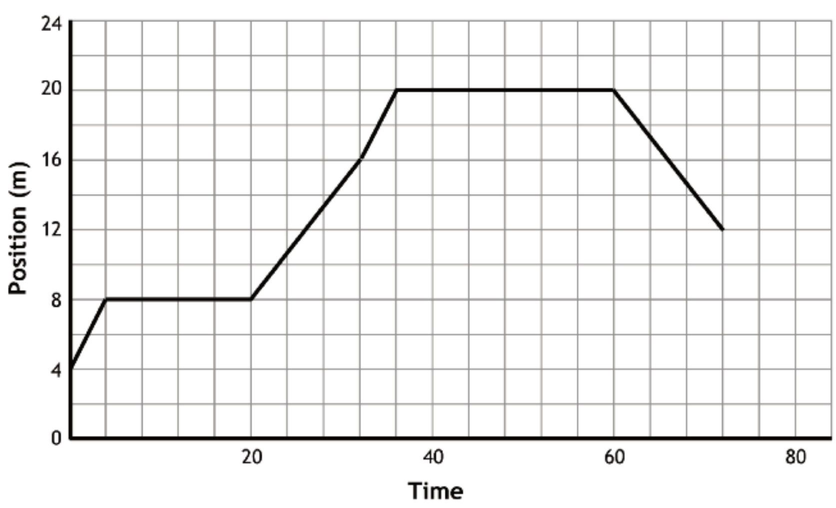
e. In the diagram above, east points to the right. During which of the intervals in #1 is the ladybug moving in the easterly direction? In the westerly direction?

Easterly direction: (a) A to B; (c) C to D; (d) C to E

Westerly direction: (b) C to B; (d) E to D

3. Below is a table showing the position above the ground floor of an elevator at various times. On the graph below the table, plot a graph of position-time.

Time (seconds)	0	4	20	32	36	60	72
Position above the ground floor (metres)	4.0	8.0	8.0	16	20	20	12



4. A worried student is waiting to see the principal. He paces back and forth in the hallway in front of the principal's office. The hallway runs north and south. The door to the office is the origin, 0 m. Here is a description of the student's motion.

   The student starts at 5.0 m N of the office door. He walks to the south for 7.0 m during 10.0 s. He stands still for 5.0 s. He turns around and walks 15.0 m N during 15.0 s. He stops to say "Hello" to a friend and remains still for 10.0 s. Finally, the principal calls him to the office door. It takes the student 10.0 s to reach the door.

   a. What is the total time the student spent in the hallway?

      $\Delta t_{\mathbf{TOTAL}}$ **= 10.0 s + 5.0 s + 15.0 s + 10.0 s + 10.0 s = 50.0 s**

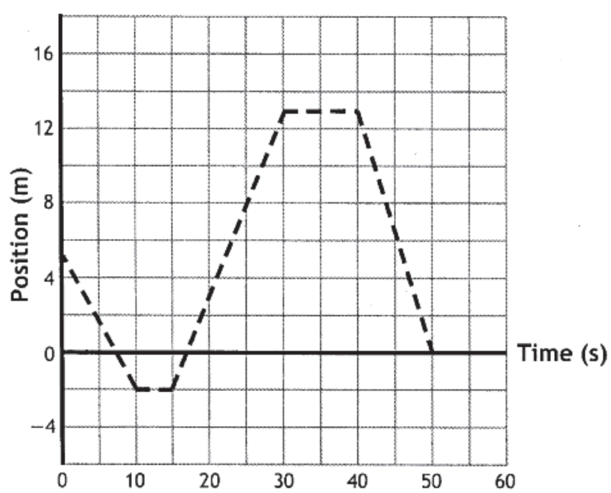
   b. What was the distance travelled by the student during his pacing?

      $\boldsymbol{\Delta d_{\mathbf{TOTAL}} = d_1 + d_2 + d_3 = 7.0\text{ m} + 15.0\text{ m} + 13.0\text{ m} = 35.0\text{ m}}$

   c. What was the average speed of the student during his pacing?

      $$\boldsymbol{\Delta v_{avg} = \frac{\Delta d}{\Delta t} = \frac{35.0\text{ m}}{50.0\text{ s}} = 0.700\text{ m/s}}$$

   d. On the graph below, plot time on the horizontal axis and position on the vertical axis. Use straight-line segments to join the points of position-time that you plot.



   e. What is the total displacement for the student's journey? Find this from the graph.

      $$\Delta\vec{d}_{\mathbf{TOTAL}} = \vec{d}_{50} - \vec{d}_0 = \mathbf{0\text{ m}} - (\mathbf{+5.00\text{ m}}) = \mathbf{-5.00\text{ m}}$$

f. What is the average velocity for the whole journey?

$$\vec{\boldsymbol{v}}_{\mathbf{avg}} = \frac{\Delta\vec{\boldsymbol{d}}}{\Delta \boldsymbol{t}} = \frac{\mathbf{-5.00\ m}}{\mathbf{50.0\ s}} = \mathbf{-0.100\ m/s}$$

5. Briefly explain the terms *speed*, *velocity,* and *uniform motion*. How are they related to one another?

Speed **is a measure of distance travelled over an interval of time. Speed is usually measured in kilometres per hour or metres per second.**

Velocity **measures displacement during a time interval. It can be considered as "speed in a stated direction." Velocity is also usually measured in kilometres per hour or metres per second. Velocity is always referred to with direction.**

Uniform Motion **refers to movement at a constant speed, without slowing down or speeding up.**

All three of these terms refer to how quickly an object moves.

LESSON 4

Learning Activity 3.5: Velocity on a Graph

1. For each of the following cases, sketch a diagram that shows initial position, final position, the direction of motion, and the elapsed time. Use this diagram to calculate the average velocity of the object.

All diagrams will use moving to the right as the positive direction.

a. A bicycle travels 36 km in 1.2 hours.

$\vec{d}_1 = 0\text{ km}$ $\Delta t = 1.2\text{ h}$ $\vec{d}_2 = +36\text{ km}$

$\vec{v}_{avg} = ?$

$$\vec{v}_{avg} = \frac{\Delta\vec{d}}{\Delta t} = \frac{+36\text{ km} - 0\text{ km}}{1.2\text{ h}} = +30\text{ km/h}$$

The average velocity of the bicycle is +30 km/h.

b. A person runs 17 m toward a bus stop in 2 seconds.

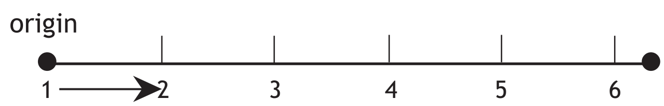
$\vec{d}_1 = 0 \text{ m}$ $\quad \Delta t = 2 \text{ s}$ $\quad \vec{d}_2 = +17 \text{ m}$

$\vec{v}_{\text{avg}} = ?$

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+17 \text{ m} - 0 \text{ m}}{2 \text{ s}} = +8.5 \text{ m/s}$$

The average velocity of the person is +8.5 m/s.

c. A car passes 6 telephone poles, each spaced 50 m apart, in 18 seconds.



$\vec{d}_1 = 0 \text{ m}$ $\quad \Delta \vec{d} = +50 \text{ m}$ $\quad \vec{d}_2 = +250 \text{ m}$

$\vec{v}_{\text{avg}} = ?$

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+250 \text{ m} - 0 \text{ m}}{18 \text{ s}} = +13.9 \text{ m/s}$$

The average velocity of the car is +13.9 m/s.

d. A toy car moves along a track from +2 cm to +26 cm in 0.5 seconds.

$\vec{d}_1 = +2 \text{ cm}$ $\quad \Delta t = 0.5 \text{ s}$ $\quad \vec{d}_2 = +26 \text{ cm}$

$\vec{v}_{\text{avg}} = ?$

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+26 \text{ cm} - (+2 \text{ cm})}{0.5 \text{ s}} = +48 \text{ cm/s}$$

The average velocity of the minivan is +48 cm/s.

2. For each example in Question 1, comment from your personal experience whether the object is moving slowly, at an average speed, or quickly, or if it has an unrealistic velocity.
   a. **For a bicycle, 30 km/h would be fast.**
   b. **Running at 8.5 m/s is fast, bordering on unrealistic for the average person. Olympic-calibre sprinters run at 10 m/s.**
   c. **The car is travelling at 13.9 m/s × 3.6 = 50 km/h. This would be a medium speed for a car.**
   d. **For a toy car, 48 cm/s is a medium speed.**

3. A skateboarder is coasting at a velocity of 2 m/s away from an intersection. If we let the intersection be the origin, how far will the boarder travel in 3.5 seconds?

   Assume that the skateboarder is coasting east, to the right, or in the positive direction.

$$\vec{v}_{avg} = +2 \text{ m/s}; \ \Delta t = 3.5 \text{ s}$$

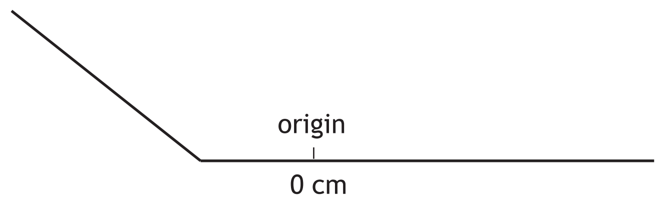
$$\vec{v}_{avg} = \frac{\Delta \vec{d}}{\Delta t}$$

$$+2 \text{ m/s} = \frac{\Delta \vec{d}}{3.5 \text{ s}}$$

$$\Delta \vec{d} = (+2 \text{ m/s})(3.5 \text{ s}) = +7 \text{ m}$$

The displacement is +7 m or 7 m to the right.

4. A toy car rolls off a ramp and onto a horizontal track with a uniform motion of 1.5 m/s. The end of the ramp is at position –12 cm. If the car reaches the end of the track in 0.4 seconds, what was the length of the track? Include a diagram and label the origin.



$\vec{d}_1 = -2$ cm $\qquad\qquad \vec{d}_2$

Since the positions are marked in cm, $\vec{v}_{avg}$ should be expressed in cm/s.

$\vec{v}_{avg} = +1.5$ m/s $= +150$ cm/s; $\Delta t = 0.4$ s

The unknown is the length of the track, $\Delta\vec{d}$.

$$\vec{v}_{avg} = \frac{\Delta\vec{d}}{\Delta t}$$

$$+150 \text{ cm/s} = \frac{\Delta\vec{d}}{0.4 \text{ s}}$$

$$\Delta\vec{d} = (150 \text{ cm/s})(0.4 \text{ s}) = +60 \text{ cm}$$

The track is 60 cm long.

Diagram A

Diagram B

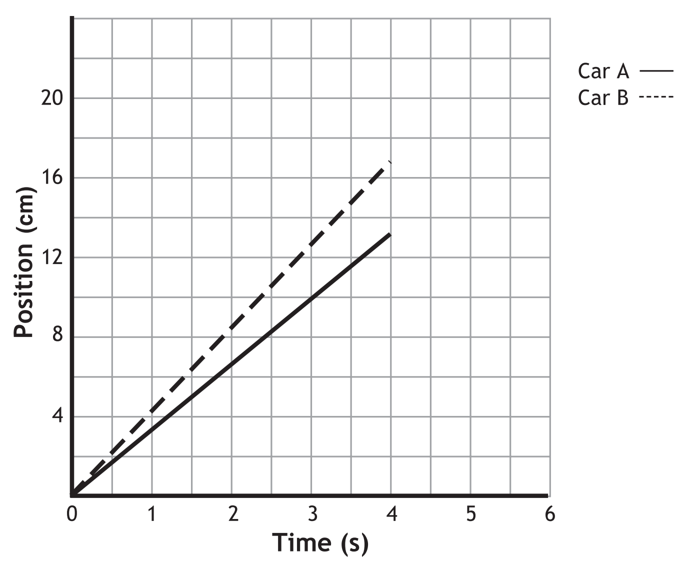
5. The above pictures were taken by a high-speed camera set up along the highway. Each car was photographed five times at one-second intervals. The five photos were then pasted together to produce the final diagrams.

a. Use a metric to measure the distance travelled by the car between each interval. Record your results in Tables A and B. Use the back of the first car as your origin (0 seconds) and measure to the nearest 0.1 centimetres.

Table A	
Position (cm)	Time (s)
0	**0**
3.4	**1**
6.6	**2**
10.0	**3**
13.3	**4**

Table B	
Position (cm)	Time (s)
0	**0**
4.10	**1**
8.20	**2**
12.30	**3**
16.40	**4**

b. Graph the data in Tables A and B on the position-time graph.



c. Calculate the average velocity for Cars A and B.

Car A:

$$\vec{v}_{avg} = \Delta\vec{d} / t$$
$$\vec{v}_{avg} = 13.3 \text{ cm} / 4 \text{ s}$$
$$\vec{v}_{avg} = 3.3 \text{ cm} / \text{s}$$

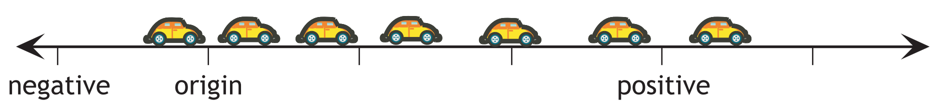
Car B:

$$\vec{v}_{avg} = \Delta\vec{d} / t$$
$$\vec{v}_{avg} = 16.40 \text{ cm} /$$
$$\vec{v}_{avg} = 4.10 \text{ cm} / \text{s}$$

LESSON 5

Learning Activity 3.6: Velocity and Acceleration

1. Use the graphic below to answer the following.



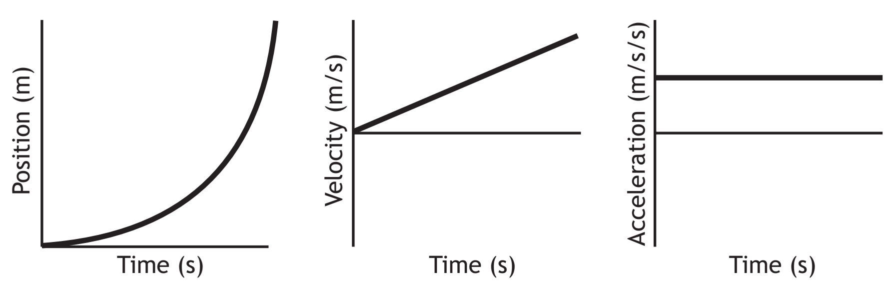
a. Describe the motion of the car.

The car is moving to the right. The velocity is non-uniform. The car is accelerating to the right, the direction of motion, since it is speeding up.

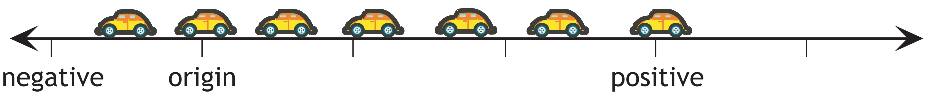
b. What is the sign of the velocity? **Positive**

c. What is the sign of the acceleration? **Positive**

d. Sketch the lines for the position-time graph, the velocity-time graph, and the acceleration-time graph that describe this motion.



2. Use the graphic below to answer the following.



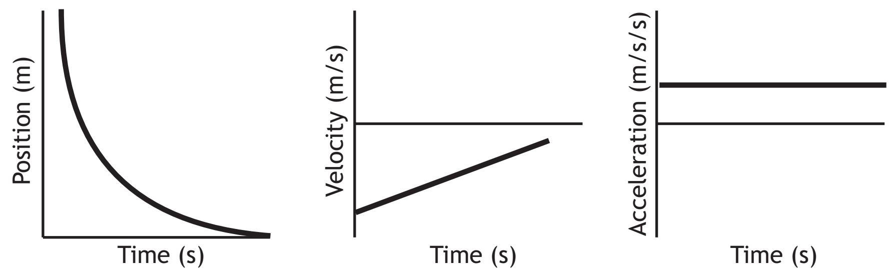
   a. Describe the motion of the car.

      The car is moving to the left, but velocity is decreasing. The acceleration is opposite to the motion since the car is slowing down.

   b. What is the sign of the velocity? **Negative**

   c. What is the sign of the acceleration? **Positive**

   d. Sketch the lines for the position-time graph, the velocity-time graph, and the acceleration-time graph that describe this motion.



3. Use the data in the table below to answer the following.

   a. Describe the motion of the object.

      The object is moving to the right but slowing down. There is an acceleration opposite to the direction of motion of the object.

Time (s)	Velocity (m/s)
0	10
1	9
2	8
3	7
4	6
5	5

   b. What is the sign of the velocity?

      Positive

   c. What is the sign of the acceleration?

      Negative

4. Use the data in the table below to answer the following.
   a. Describe the motion of the object.

      The object is moving to the left and speeding up. The velocity is increasing in the negative direction, so the acceleration acts in the direction of motion.

Time (s)	Velocity (m/s)
0	–4
1	–8
2	–12
3	–16
4	–20
5	–24

   b. What is the sign of the velocity?

      Negative

   c. What is the sign of the acceleration?

      Negative

5. Use the data in the table below to answer the following.
   a. Describe the motion of the object.

      The object is moving to the left but the velocity is decreasing. The acceleration acts in a direction opposite to the velocity.

Time (s)	Velocity (m/s)
0	–11
1	–9
2	–7
3	–5
4	–3
5	–1

   b. What is the sign of the velocity?

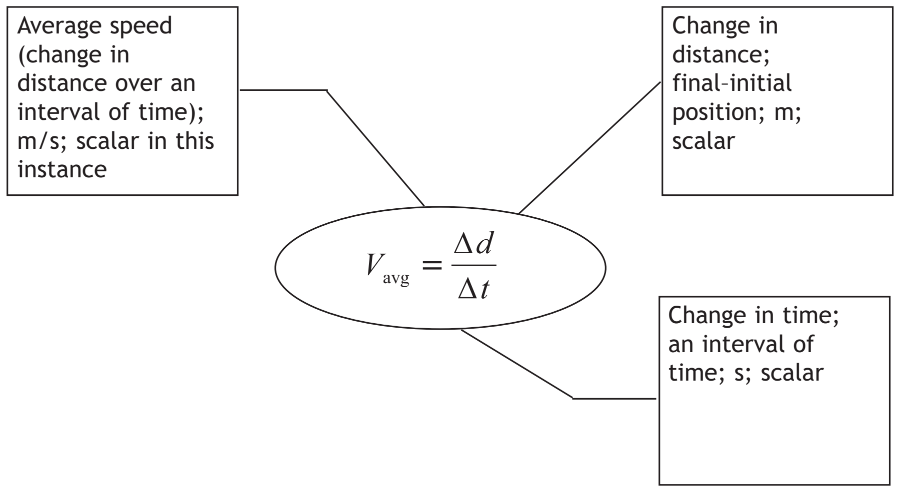
      Negative

   c. What is the sign of the acceleration?

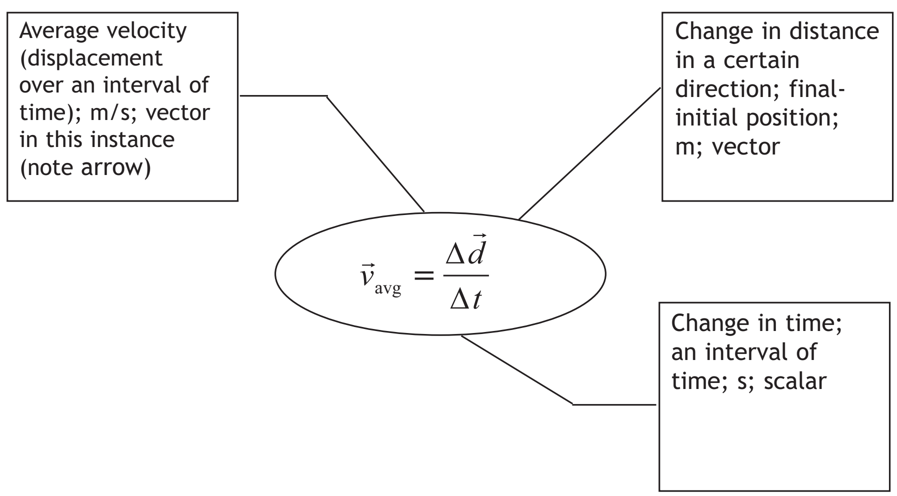
      Positive

6. For each symbol in the following equations, give the name of the quantity, a definition, its unit, and whether it is a vector or scalar. Write the information around each rectangle.

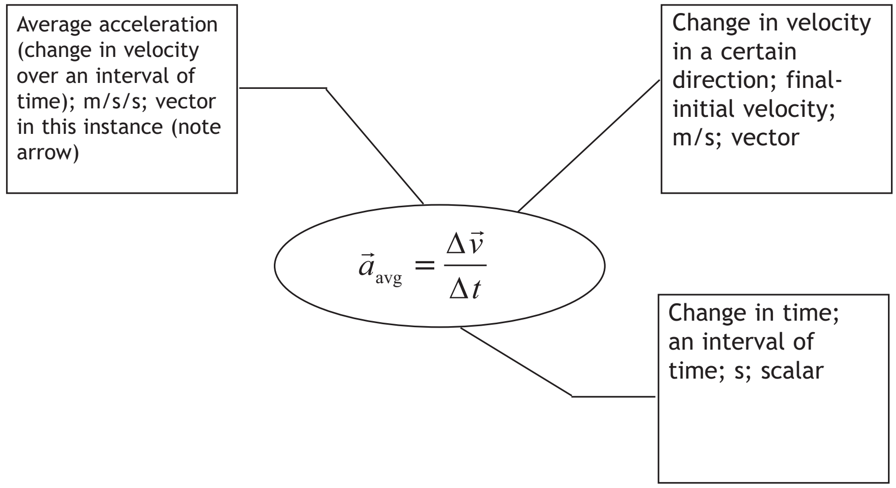
a.



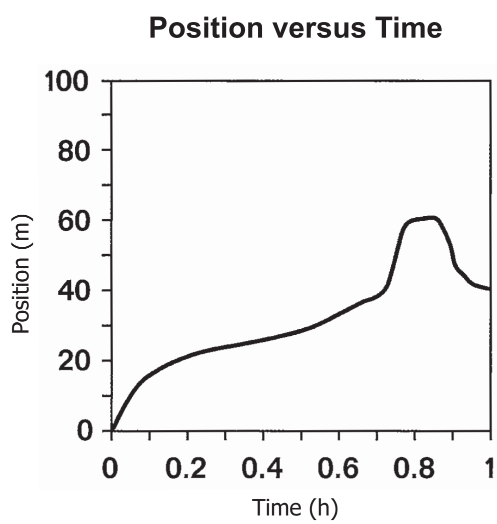
b.



c.



7. From the graph below, calculate the average velocity between the following points and comment whether or not the average velocity closely approximates the instantaneous velocity at the midpoint of the interval.



The average velocity is found by taking the slope of the line on the position-time graph for that time interval.

The instantaneous velocity is found by locating the position on the curve of the position-time graph for the instant in question. Draw a tangent at that point in time. The slope of this line segment represents the instantaneous velocity. Note that since this line is estimated, this can lead to wide variations in the slope.

a. $t_1 = 0$ h and $t_2 = 0.1$ h

Average velocity:

$$t_1 = 0 \text{ h} \qquad \vec{d}_1 = 0 \text{ m}$$

$$t_2 = 0.1 \text{ h} \qquad \vec{d}_2 = +15 \text{ m}$$

$$\vec{v}_{\text{avg}} = ?$$

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+15 \text{ m} - 0 \text{ m}}{0.1 \text{ h} - 0 \text{ h}} = \frac{+15 \text{ m}}{0.1 \text{ h}} = +150 \text{ m/h}$$

Instantaneous velocity:

From the line drawn on the graph at 0.05 h, the following points are taken.

$$t_1 = 0 \text{ h} \qquad \vec{d}_1 = 0 \text{ m}$$

$$t_2 = 0.4 \text{ h} \qquad \vec{d}_2 = +60 \text{ m}$$

$$\vec{v}_{0.05} = ?$$

$$\vec{v}_{0.05} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+60 \text{ m} - 0 \text{ m}}{0.4 \text{ h} - 0 \text{ h}} = \frac{+60 \text{ m}}{0.4 \text{ h}} = +150 \text{ m/h}$$

The two velocities are equal.

b. $t_1 = 0.2$ h and $t_2 = 0.4$ h

Average velocity:

$$t_1 = 0.2 \text{ h} \qquad \vec{d}_1 = +20 \text{ m}$$

$$t_2 = 0.4 \text{ h} \qquad \vec{d}_2 = +26 \text{ m}$$

$$\vec{v}_{\text{avg}} = ?$$

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+26 \text{ m} - (+20 \text{ m})}{0.4 \text{ h} - 0.2 \text{ h}} = \frac{+6 \text{ m}}{0.2 \text{ h}} = +30 \text{ m/h}$$

Instantaneous velocity:

From the line drawn on the graph at 0.3 h, the following points are taken.

$t_1 = 0 \text{ h}$ $\qquad \vec{d}_1 = +14 \text{ m}$

$t_2 = 1 \text{ h}$ $\qquad \vec{d}_2 = +48 \text{ m}$

$\vec{v}_{0.3} = ?$

$$\vec{v}_{0.3} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+46 \text{ m} - (+14 \text{ m})}{1 \text{ h} - 0 \text{ h}} = \frac{+32 \text{ m}}{1 \text{ h}} = +32 \text{ m/h}$$

The two velocities are almost equal.

c. t_1 = 0.6 h and t_2 = 0.8 h

Average velocity:

$t_1 = 0.6 \text{ h}$ $\qquad \vec{d}_1 = +32 \text{ m}$

$t_2 = 0.8 \text{ h}$ $\qquad \vec{d}_2 = +60 \text{ m}$

$\vec{v}_{\text{avg}} = ?$

$$\vec{v}_{\text{avg}} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+60 \text{ m} - (+32 \text{ m})}{0.8 \text{ h} - 0.6 \text{ h}} = \frac{+28 \text{ m}}{0.2 \text{ h}} = +140 \text{ m/h}$$

Instantaneous velocity:

From the line drawn on the graph at 0.05 h, the following points are taken.

$t_1 = 0 \text{ h}$ $\qquad \vec{d}_1 = 0 \text{ m}$

$t_2 = 1 \text{ h}$ $\qquad \vec{d}_2 = +54 \text{ m}$

$\vec{v}_{0.7} = ?$

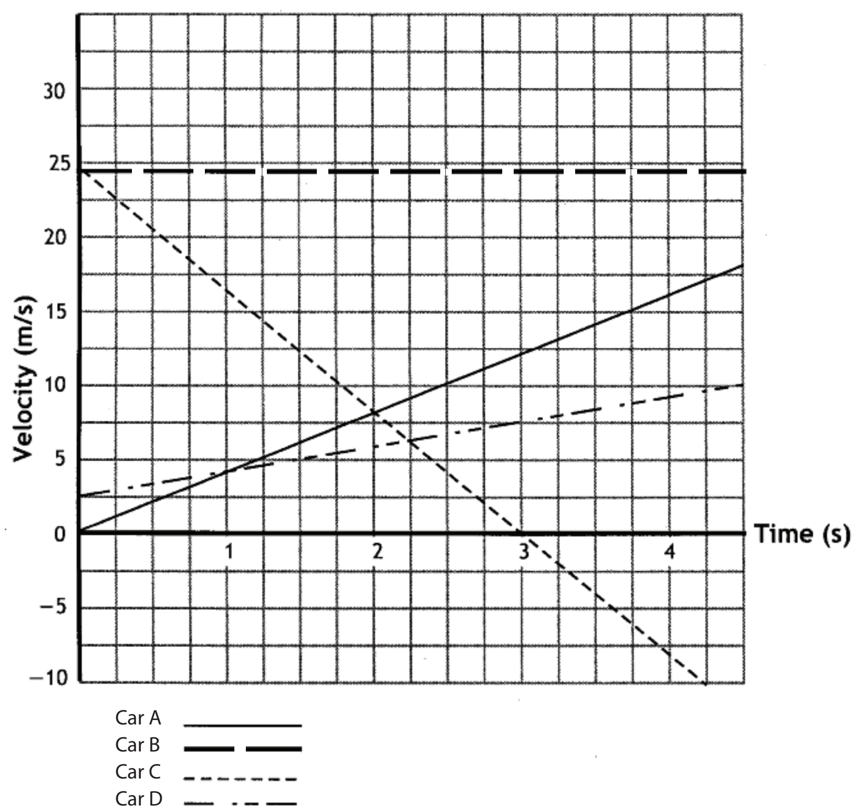
$$\vec{v}_{0.7} = \frac{\Delta \vec{d}}{\Delta t} = \frac{+54 \text{ m} - 0 \text{ m}}{1 \text{ h} - 0 \text{ h}} = \frac{+54 \text{ m}}{1 \text{ h}} = +54 \text{ m/h}$$

The two velocities are not equal.

8. The table below shows the velocity in metres-per-second of four different cars. Draw the velocity-time graph for each vehicle on the provided graph.

	Time					
		0.0	**1.0 sec**	**2.0 sec**	**3.0 sec**	**4.0 sec**
Velocity (m/s)	**Car A**	0.0	4.0	8.0	12.0	16.0
	Car B	24.0	24.0	24.0	24.0	24.0
	Car C	24.0	16.0	8.0	0.0	–8.0
	Car D	2.0	4.0	6.0	8.0	10.0

Velocity-Time Graph



9. Find the acceleration in each case.

All the calculations of acceleration will use the following equation:

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_{final} - \vec{v}_{initial}}{t_{final} - t_{initial}}$$

The units used will be those given in the question.

a. A car increases its velocity from 0 km/h to 20 km/h in 6 seconds.

$\vec{v}_1 = 0 \text{ km/h}$

$\vec{v}_2 = +20 \text{ km/h}$

$\Delta t = 6 \text{ s}$

$\vec{a}_{avg} = ?$

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_{final} - \vec{v}_{initial}}{t_{final} - t_{initial}}$$

$$= \frac{+20 \text{ km/h} - 0 \text{ km/h}}{6 \text{ s}} = +3.3 \text{ km/h/s}$$

b. A train crosses a boulevard at 10 km/h and begins accelerating as it heads out of the city. Thirty minutes later it crosses another road at 60 km/h. What is the average acceleration of the train during this period of time?

$\vec{v}_1 = +10 \text{ km/h}$

$\vec{v}_2 = +60 \text{ km/h}$

$\Delta t = 30 \text{ minutes}$

$\vec{a}_{avg} = ?$

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_{final} - \vec{v}_{initial}}{t_{final} - t_{initial}}$$

$$= \frac{+60 \text{ km/h} - (+10 \text{ km/h})}{30 \text{ min}} = +1.67 \text{ km/h/min}$$

c. A truck travelling west at 50 km/h pulls out to pass another vehicle that is moving at a constant velocity. The truck increases its velocity to 60 km/h in 6 seconds.

$\vec{v}_1 = +50 \text{ km/h}$

$\vec{v}_2 = +60 \text{ km/h}$

$\Delta t = 6 \text{ s}$

$\vec{a}_{\text{avg}} = ?$

$$\vec{a}_{\text{avg}} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_{\text{final}} - \vec{v}_{\text{initial}}}{t_{\text{final}} - t_{\text{initial}}}$$

$$= \frac{+60 \text{ km/h} - (+50 \text{ km/h})}{6 \text{ s}} = +1.67 \text{ km/h/s}$$

LESSON 6

Learning Activity 3.7: Student Investigation

1. What patterns did you notice in your data? Was there any connection between the angle of Incline B and the average height that the car was able to rise?

   As you decreased the angle of Incline B, the car should have travelled higher up Incline B.

2. In an ideal scenario, Galileo predicted that objects travelling on a U-shaped incline would return to its original height. Do your results agree with this prediction? If not, how can you explain this difference?

   Theoretically, the object should travel up the upward-sloping ramp and reach the same vertical height as the point of release. Due to friction and the loss of energy to other forms, the object is unable to return to its original height.

Learning Activity 3.8: Theories of Motion

	Aristotle	Galileo	Newton
How were his theories similar to the others?	His theories related to motion of an object.	His theories also related to the motion of an object in an ideal world.	His laws apply to all moving objects and objects at rest.
How were his theories different from the others?	He believed that an object will only move as long as there is a force acting on that object. His theories were simple.	He believed that friction, and not removing a force, is the reason an object will come to rest. His theories were more complex.	Newton believed that an object will only move when the forces acting on that object are not in balance (equilibrium).
How do these theories relate to motion of a moving car?	According to Aristotle, a car will come to a stop once you take your foot off the gas.	A car will continue to move once you take your foot off the gas, and will eventually come to a stop due to gravity.	Once you apply the brakes in a car, the passengers will continue to move forward with the same speed and direction, until another force acts upon them.

LESSON 7

Learning Activity 3.9: Forces in Action

1. Explain why a person wearing a cast on one leg becomes more tired than usual by the end of the day.

   When a person wears a cast, the weight of the leg is increased. If there is more mass, then it takes more force to move the leg. Since the leg has more mass and more inertia, a person will become easily fatigued by the amount of force necessary to move it.

2. Suggest reasons why large vehicles such as vans and trucks tend to have larger engines and higher rates of fuel consumption than smaller and more compact cars.

   Larger vehicles have a bigger mass and require more force to speed up and slow down. Since vehicles such as trucks have more mass and more inertia, it will take more force to change their state of motion. Having a bigger engine means more power will be supplied to move the massive vehicle. This is not necessary for smaller and more compact vehicles.

3. Use Newton's laws to explain why people in a car often get neck injuries like whiplash when struck from behind.

   When a vehicle is in motion, the passenger moves at the same speed and in the same direction as the vehicle. The cars and the passengers have inertia as well, which means that they resist changes in motion. When a car is hit from behind, it speeds up because a force has been applied to it. However, the passenger's inertia resists this change. The passenger's head is above the seat and will lag behind the body as it gets pushed forward by the car seat. If the passenger's head is not supported by a headrest, it lags so far behind the body that it appears to snap backward (the body is actually snapped forward). This quick movement of the head causes neck injuries commonly referred to as whiplash.

4. Explain why small rabbits can often escape bigger and faster bobcats in pursuit by zigzagging as they run.

   Small rabbits have less mass and therefore less inertia than bigger animals, such as the bobcat. This means that the rabbit is more agile and can easily overcome its own inertia to change its state of motion. Every time that rabbit does a zig or a zag, it is changing directions. This change of motion is more easily accomplished by a smaller animal with less inertia.

5. Predict when serious injuries are more likely to occur: when a car crashes into a large tree or into a wooden fence.

   Serious injuries are more likely to occur when a car crashes into a large tree. A large tree has a large mass and is further supported by a deep root system. Since the tree has so much inertia, it would be hard to make it move. In a collision with a large tree, the car and its passengers would be stopped abruptly. The kinetic energy of the car has to be converted (remember the law of conservation of energy) into other forms. In this case, the car will be deformed and pieces will fly off. The passengers will have inertia and energy, too, and in stopping, they will have to convert their kinetic energy into something else. Unfortunately, hitting the inside of the vehicle will cause their bodies to change shape and, possibly, break bones or injure soft tissues.

If, on the other hand, the car were to strike a fence, because the fence has much less mass than a tree, it has less inertia and, therefore, would move much more easily. The car would likely take a longer time to stop, giving the vehicle and passengers more time to lose kinetic energy a little at a time, causing less damage and injury.

LESSON 8

Learning Activity 3.10: The Velocity of a Car on an Inclined Plane

1. Write a concluding paragraph (i.e., what can you conclude, based on your observations?).

   What you should have observed is that as velocity increases, so does the distance the ball or marble travelled. This means that the faster you drive, the more inertia your car and its passengers will also have.

2. How could seat belts and air bags be effective means of saving lives in car collisions?

   Seat belts and airbags could be effective means of saving lives in car collisions because they will decrease the blow of an impact. After the initial collision, when inertia is quickly reduced to zero, the passenger continues to travel at the same speed the car was travelling. This means the passenger will hit the dashboard or steering wheel to reduce their speed. Devices like airbags will help to cushion the trauma of this impact. Also, in a car crash it is not unusual for the unrestrained passengers to be thrown from the vehicle, as you will learn in the next lessons.

3. **Student answers will vary.**

LESSON 9

Learning Activity 3.11: Action and Reaction Forces

1. Identify the action and reaction forces in the following situations. Also provide what the observed result of the pair of forces is and why this occurs.

   a. A hockey player pushes forward with her skates.

      Action force: **The skates push forward on the ice.**

Reaction force: **The ice pushes backward on the skates.**
Observed result: **The hockey player moves backward because the ice and the ground underneath are much more massive.**

b. You jump off of an untied canoe onto a dock.

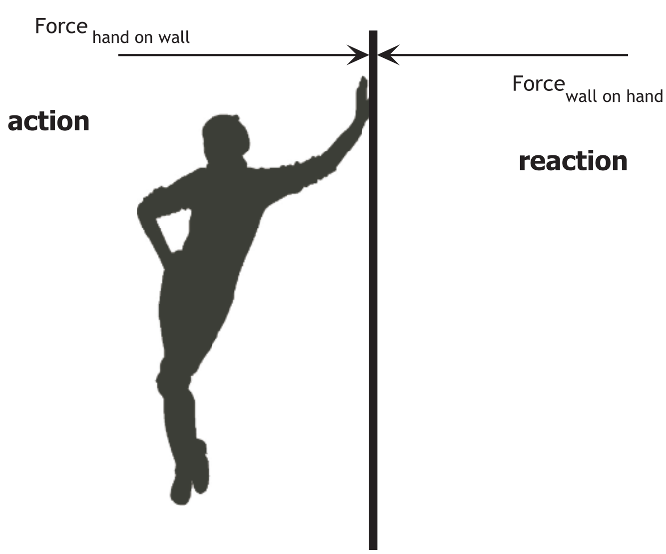
Action force: **You push backward on the canoe.**
Reaction force: **The canoe pushes forward on you.**
Observed result: **Both you and the boat will move in opposite directions. Because the canoe's mass is probably less than yours, it will go backward faster than you will go forward. You may end up in the water because the canoe's push on you was not big enough to get you to the dock.**

c. Gravity pulls on a hammer someone dropped.

Action force: **Earth's gravity pulls downward on the hammer.**
Reaction force: **The hammer's gravity pulls upward on Earth.**
Observed result: **The hammer accelerates toward Earth because Earth is so much more massive. Earth is also accelerated toward the hammer, but this acceleration is so small that it is nearly zero.**

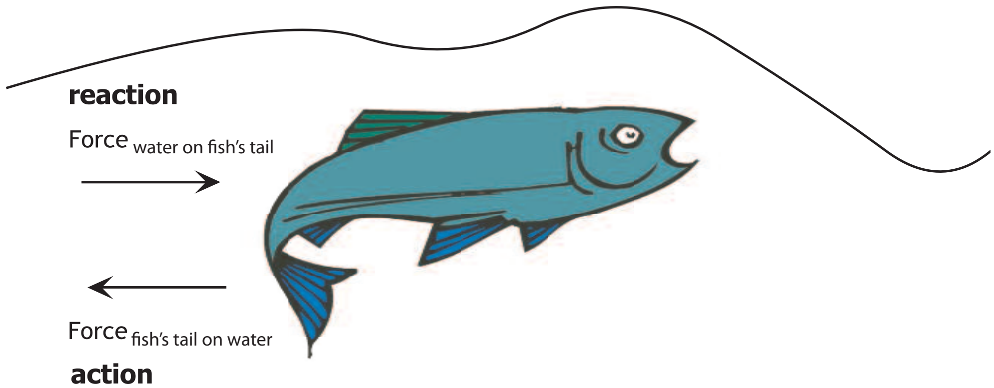
2. In each of the following cases, sketch the situation and label the action-reaction pairs.

   a. a person leans against a wall



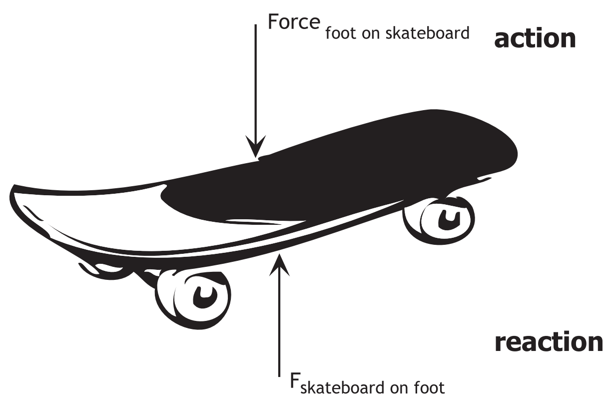
b. a fish swims

The fish's tail pushes water one way and is propelled in the opposite direction.



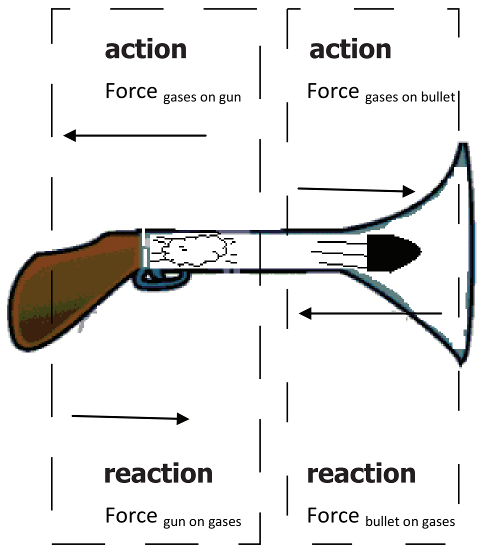
c. a skateboarder jumps

When jumping, the skateboarder pushes down on the skateboard with his or her foot. The skateboard pushes up on the skateboarder with an equal but opposite force.

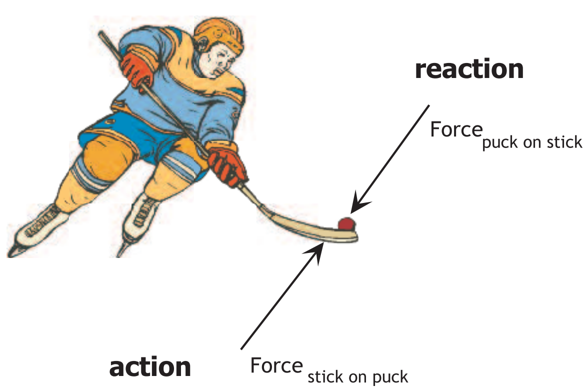


d. a gun recoils

There are two events happening in a gun.
The expanding gases push backward on the gun, while the gun pushes the gases forward out the barrel.
The gases push the bullet forward, while the bullet pushes the gases backward.



e. a hockey player's slapshot



2. While driving down the road, a mosquito collides with the windshield of your car. Which of the two forces is greater: the force that the mosquito exerts on the windshield, or the force that the windshield exerts on the mosquito?

   Newton's third law says, for every action force there is an equal and opposite reaction force. Therefore, the amount of force the mosquito exerts on the windshield is exactly the same as the amount of force the windshield exerts on the mosquito. However, using Newton's second law (*F*=*ma*), because the mosquito has such small mass, it has an

incredible acceleration in the reverse direction—too much for its tiny body. The force on the windshield is not enough to give it any appreciable acceleration backward.

3. Two students are facing each other while standing on their skateboards. One student throws a large medicine ball to the other student. Describe what happens in terms of force and motion.

   As the student throws the medicine ball, he/she will start to accelerate backwards on the skateboard. The action force is the student pushing the ball in a forward direction, and thus the reaction force will be for the ball to push the student and skateboard in a backward direction.

4. In terms of action-reaction force pairs, explain why it is important to use helmets, elbow pads, knee pads, and other protective clothing when using skateboards or in-line skates.

   When using any recreational equipment, there is always the risk of accidents, such as falling or colliding with other objects. In any type of accident, you will serve as the action force, while the ground or other object you collide with will provide the reaction force. For example, if you "wipe out" while skateboarding, the ground will push against you with a large amount of force. While the ground will not get injured, you surely will, so protect yourself and avoid injury.

Lesson 10

Learning Activity 3.12: Momentum of Objects

1. In the following table, order the objects listed below according to their momentum. Comment on the reasoning for your choices.

   Transit bus, football pass, sprinter, statue, race car, marathon runner, slapshot hockey puck, building, skateboarder

Sample Responses (Answers May Vary)

Object	Amount of Momentum	Comments
transit bus	high	Speed of the bus will affect its momentum (more speed = more momentum). Difficult to bring momentum to zero.
race car	high	A car with higher velocity or more mass will have greater momentum. Difficult to bring momentum to zero.
slapshot	high	While a puck has little mass, it travels at a high velocity and it is difficult to bring its momentum to zero.
sprinter	moderate (medium)	Mass and velocity will cause momentum to vary from one athlete to another.
marathon runner	moderate (medium)	Momentum will vary. Olympic marathon runners are very light but run very fast. Recreational marathoners could have more mass and slower speed
skateboarder	moderate (medium)	The velocity and mass of the person will affect the momentum.
football pass	little (small)	The mass of the ball is very small and so is the velocity.
building	no momentum	A building is already at rest.
statue	no momentum	A statue is already at rest.

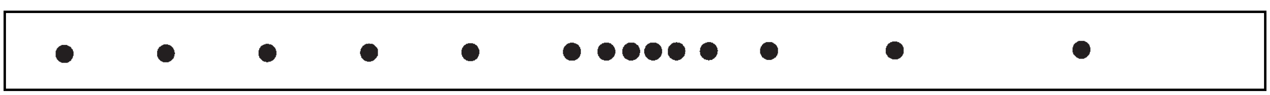
2. Estimate the velocity of the objects in km/h and calculate their momentum. Compare the momentum results to your order in the previous table.

Object	Mass (kg)	Velocity (km/h)	Momentum (kg • km/h)	Comments
transit bus	8000	**50**	**400 000**	**More velocity = more momentum**
football pass	0.5	**10**	**5**	**If you throw the ball with more force, it will have more momentum.**
sprinter	75	**25**	**1875**	**More velocity = more momentum**
Golden Boy statue	1650	**0**	**0**	**No momentum**
NASCAR stock car	1545	**300**	**463 500**	**The faster the car, the more momentum it has.**
marathon runner	65	**15**	**975**	**More velocity = more momentum**
slapshot	0.15	**40**	**6**	**More velocity = more momentum**
building	1 000 000	**0**	**0**	**No momentum**
skate-boarder	68	**10**	**680**	**More velocity = more momentum**

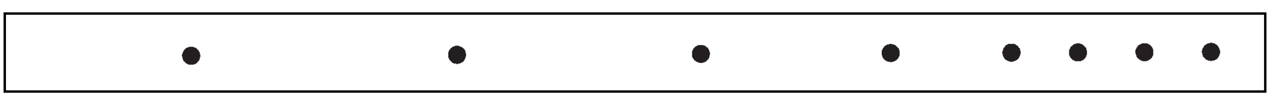
Learning Activity 3.13: Momentum and Impulse

1. Impulse depends on both force and time. Give an example for each case:
   a. a large force for a short time
      – **hitting a baseball with a bat, hitting a golf ball**
      – **two cars crashing together**
   b. a small force for a long time
      – **coasting to a stop while riding a bicycle**
      – **a sliding curling rock coming to a stop**
   c. a large force for a long time
      – **a train speeding up or slowing down**
      – **a large boat or ship speeding up or slowing down**
   d. a small force for a short time
      – **moving an egg**
2. Two cars of equal mass are driving down Portage Avenue with equal velocities. They both come to a stop over different lengths of time. The ticker tape patterns for each car are shown on the diagram below:

Car A



Car B



   a. At what approximate location on the diagram (in terms of dots) does each car begin to experience an impulse?
      Car A experiences an impulse after six dots.
      Car B experiences an impulse after one dot.

b. Which car (A or B) experiences the greatest change in momentum? Explain.

Car A slowed to one-third of its original velocity. The change in momentum is a loss of two-thirds of the original.

Car B slowed to one-quarter of its original velocity. The change in momentum is a loss of three-quarters of the original.

Car B experiences the larger momentum change.

c. Which car (A or B) experiences the greatest impulse? Explain.

Since Car B experienced the larger momentum change, it experienced the greater impulse.

LESSON 11

Learning Activity 3.14: Safety First

1. Besides cars, what are some other machines or structures that might use crumple zones, air bags, rollover cages, or bumpers? See if you can think of one machine or structure per safety feature.

   Crumple Zone
   The packaging of objects like televisions, computer monitors, etc., uses rigid foam to keep the object in place in the centre of a box. There is a space between the object and the box so that the box can crumple to absorb some of the energy in a collision without damaging the contents.

   Air bags
   Hollywood stuntmen use large air bags to cushion their falls from a great height. Air bags are used in packaging as bubble wrap.

   Rollover Cages
   Farm tractors use rollover bars above the driver. Tractors tend to flip over backwards; that is, the front end lifts up and swings up over the driver. The rollbar protects the driver from being crushed in the event of a rollover. Tractors used on hillsides where they may topple over on their sides also use rollbars.

   Bumpers
   Bumpers are used on industrial equipment such as moving platforms, conveyers, etc. The bumpers prevent damage to other equipment and to humans in case of collisions.

Lesson 12

Learning Activity 3.15: Conservation of Energy

1. For each of the following examples, describe the transformation of energy that has occurred:

   a. a child on a pogo stick

      The kinetic energy is transferred to the pogo stick, which compresses at the bottom (where the spring will tightly coil), and is stored as potential energy. Then, as the spring rebounds, the potential energy is released in the form of kinetic energy, which will send the child and the pogo stick into the air. As the pogo stick gets higher in the air, potential energy again increases as there is more gravitational pull on the child and pogo stick. Remember that when an object is in motion, there must be kinetic energy. Since energy cannot be destroyed, it will be stored as potential energy for later use or to be converted to other forms.

   b. a pole vaulter

      There is potential energy in the pole as it bends (the same as a spring), which is then converted to kinetic energy as the athlete is thrown into the air. As the athlete comes to the top of the arc in the air, her potential energy increases so that she will hit the ground with the same speed with which she took off from the ground.

   c. A car shoots through the intersection that you are approaching in your car. You brake hard to avoid the other car and leave skid marks on the road. You cannot avoid hitting the other car and you hear a loud crash as you collide.

      Skid marks left on the road are an indication that there was friction between the tires and the pavement. Friction usually causes heat, and this is one way that the kinetic energy from the car's motion is transformed. As the cars collide, the loud crash is also a conversion of energy in the form of sound. The collision may also cause some damage and crumpling of the car's body, which is also converted from kinetic energy.

Lesson 13

Learning Activity 3.16: Friction Factors

1. Suggest ways to reduce friction between a bicycle and the road. What could you change about your bike, and what could you change about the road?

   You could reduce the friction between a bicycle and the road by using slimmer tires that are smooth (like the tires on a racing bike). Choosing a smooth pavement versus a rough surface would also reduce the friction between the road and the tires. If the pavement was wet, icy, or was covered with loose sand, then friction would be even further reduced.

2. Discuss why skiers and snowboarders use wax.

   Skiers and snowboarders use wax on the surface that comes in contact with the snow. Depending on the type of snow that has fallen, a skier might choose a wax that will reduce friction so that he glides over the snow with ease and more speed. On a different day, a snowboarder might opt for a wax that is sticky and will provide a bit of friction for better control but less speed.

3. In what ways would a surface with little or no friction make driving dangerous?

   A surface with no friction would make driving very dangerous. When braking, you would need extremely long distances to stop, since friction would not help you slow down and stop. This would surely cause many more collisions than we see now. As well, changing directions would be dangerous, since when you turn the wheel, you might not turn and you might lose control of your vehicle. In order to maintain some safety, driving would have to be done at very slow speeds.

4. What objects might you keep in your trunk for the winter, in the event you are stranded in the snow and need extra traction on your wheels?

   You might keep chains to wrap around your tires (or to use if you need to be towed by another car), large pieces of sandpaper and wooden wedges, or a bag of sand or kitty litter.

5. Describe how the following conditions would affect your ability to stop a moving vehicle.

   a. a car with new tires on a dry road

      lots of friction, normal braking distance

   b. a car with new tires on a wet road

      reduced friction, longer braking distance

c. a car with worn tires on a wet road

very reduced friction, much longer braking distance

d. a car with new tires on slick ice

reduced friction, increased braking distance

Learning Activity 3.17: Braking Factors

1. Describe the relationship between reaction time and braking distance.

   As reaction time increases, so does braking distance. Let's say it was already going to take 200 m to come to a complete stop, given the road conditions. If you continue driving for 20 m while you register the need to brake, then your stopping distance is actually 220 m.

2. Explain why drinking and driving don't mix.

   Drinking and driving are a bad combination, because alcohol might make you feel more alert but it actually slows down the central nervous system. Therefore, alcohol will actually cause you to need more time to react. By having a slow reaction time (the more you drink, the slower it gets), you become a very dangerous driver.

3. Identify substances that, when ingested, will have a negative effect (by slowing you down) on reaction time.

   Substances that could slow down your reaction time include the following: alcohol, antidepressants, some cold and flu medication, sleep aids, hallucinogens, and some allergy medications. If ever you are not sure, ask someone.

4. Discuss why braking distance on a gravel road is greater than that on a paved road.

   Gravel that is loose still moves under your tires. When your tires need to grip a surface to create friction and stop, the gravel will spin out from underneath the tires and shift around. This means that gravel actually increases braking time rather than allowing you to stop faster.

5. When driving, what factors should you assess in order to prepare yourself for the required braking distance?

   When you get in the car to drive somewhere, you should observe the following factors and adjust your speed and braking time accordingly: road conditions (wet, dry, etc.), visibility, your health, and the condition of your car and tires.

LESSON 15

Learning Activity 3.18: Calculating Braking Distance

1. You are driving on a side road that is not paved. There is a sign that indicates the frictional constant of the surface is 0.12. How does this information help you drive safely?

   The frictional constant of 0.12 is quite far from 0 and indicates that the surface does not supply much friction. You should then slow down and be prepared to brake far in advance of the point where you need to stop.

2. What would be the required stopping distance for a car travelling at 100 km/h on an ice road in northern Manitoba? (You will have to convert km/h into m/s by multiplying by a conversion factor—km/h ÷ 3.6 = m/s.)

   Using the relationship $d = kv^2$ the braking distance would be as follows:
   $d = (0.15)\ (100 \div 3.6\ \text{m/s})^2$; $d = 115\ \text{m}$
   (That's more than a soccer field!)

3. Calculate and then compare the braking distances for a car travelling at 30 km/h and a car travelling at 90 km/h on a wet concrete street. What do you conclude?

   At 30 km/h: $d = (0.10)(30 \div 3.6\ \text{m/s})^2 = 6.94\ \text{m}$
   At 90 km/h: $d = (0.10)(90 \div 3.6\ \text{m/s})^2 = 62.5\ \text{m}$
   At 90 km/h the braking distance is 32 times as long as at 30 km/h.

LESSON 16

Learning Activity 3.19: Stop for a Minute

1. Calculate the total stopping distance for a car that is travelling at 60 m/s on a rain-soaked road (use 1.5 seconds as the driver's reaction time).

   $d = kv^2$
   60 km/h = 60/3.6 m/s = 16.7 m/s
   $d = (0.10)(16.7\ \text{m/s})^2 = 27.8\ \text{m}$ (This is the braking distance.)
   If reaction time is 1.5 s, then:
   Distance = velocity × time; $d = (16.7\ \text{m/s})(1.5\ \text{s}) = 25.05\ \text{m}$
   Total stopping distance = 27.8 m + 25.05 m = 52.85 m
   52.85 m is the total stopping distance.

2. The light turns yellow at the upcoming intersection, which is 85 metres away. You are travelling at 60 km/h on dry pavement. Will you be able to stop before the light turns red?

   $d = kv^2$
   $d = (0.06)(16.7\ m/s)^2 = 16.7\ m$ (This is the braking distance.)
   Distance = velocity × time (for reaction time distance). Assume 1.5 s for reaction time.
   $d = (16.7\ m/s) \times (1.5\ s) = 25.05\ m$
   Total stopping distance = 25.05 m + 16.70 m = 41.75 m
   Therefore, you would be able to stop before the light turned red.

3. a. The average reaction time for a healthy, alert person is 1.5 seconds. How would a delayed reaction time affect your total stopping time?

      A delayed reaction time will mean that you will cover more distance before you realize that you need to brake. This will then increase your total stopping time and give you a smaller margin of error when judging the time you have to brake.

   b. What factors might cause your reaction time to be delayed?

      Some factors that may delay your reaction time are distractions (music, calling on a cellular phone, watching the side of the road, talking when driving, having a lot on your mind), fatigue (not being alert), and some medications that induce a feeling of drowsiness.

4. A pedestrian wearing dark clothing at night is only visible at a distance of about 35 m to a driver using low beams. Calculate the maximum speed at which a car could travel so that a driver could brake and avoid a collision (assume a 1.5 second reaction time and dry pavement).

   A speed of 60 km/h would seem to be a good guess to be able to stop in 35 m.
   The calculation of stopping distance requires the calculation of reaction distance using $\Delta d = v\Delta t$ plus the calculation of braking distance using $\Delta d = kv^2$. In both cases, v must be in m/s.
   At 60 km/h: $v = 60/3.6 = 16.7$ m/s and $\Delta t = 1.50$ s
   Reaction distance: $\Delta d = v\Delta t = (16.7\ m/s)(1.50\ s) = 25.0\ m$
   Braking distance is 16.7 m.
   Total stopping distance is 41.7 m. The pedestrian would be struck by the car.

   If we try a speed of 50 km/h, we get the following stopping distance.
   $V = 50/3.6 = 13.9$ m/s and $\Delta t = 1.50$ s
   Reaction distance: $\Delta d = v\Delta t = (13.9\ m/s)(1.50\ s) = 20.8\ m$
   Braking distance: $d = kv^2 = (0.06)\ (13.9\ m/s)^2 = 11.6\ m$
   Stopping distance = 32.4 m.
   A car would have to be travelling at about 50 km/h in order to stop in time to avoid hitting the pedestrian.

5. Some driver education experts recommend that "when the vehicle ahead of you passes a certain point, such as a sign, count 'one-thousand-one, one-thousand-two, one-thousand-three.' This takes about 3 seconds. If you pass this same point before you finish counting, you are following too closely." They also suggest a "4 second or more cushion" in inclement weather. Using the laws of physics and your understanding of braking distance, write a rationale for this rule.

   The three-second rule for a safe following distance allows the driver of the second car to travel during his reaction time of 1.5 s without braking, then hit the brakes and still stop in time to avoid a collision with the car ahead.

   The braking distance varies with the square of the speed of the car. If the speed doubles, the braking distance increases by a factor of 4. However, since both cars are assumed to brake equally well, the braking distance will be the same for each vehicle.

   If cars follow at a certain distance, say 10 m, this may be more than the reaction distance at a low speed. As the speed increases, the reaction distance increases in proportion to the speed of the vehicle. If the speed doubles, the reaction distance doubles. Therefore the 10 m following distance would no longer be a safe following distance.

   However, if following time is used, the car will automatically increase the following distance to keep it safe. In 3 s the car will travel twice as far if the speed is doubled. Since this is now the following distance, it will be a safe distance. The car will be able to stop in the reaction distance.

   In inclement weather, the braking distance is affected. Braking distance increases. The extra second provides a larger following distance, a cushion, which can be used up by the extra braking distance the second car may have.

LESSON 17

Learning Activity 3.20: Collision Scenario

1. What different choices could the teens have made to possibly avoid this tragedy?
   - **The driver might have chosen not to offer his friends a ride.**
   - **The driver might have suggested that the group of boys use their bikes to get to their destination.**

- **The group of boys could have asked another, more experienced driver to give them a ride, if another mode of transportation was not available or reasonable.**
- **The driver could have driven at a slower speed, which would have reduced the impact upon collision with the Honda.**
- **The driver could have minimized distractions in the car, and perhaps avoided driving off the road.**

2. Who are all the people affected in this scenario? In what ways are these people affected?

   The affected parties include

   - **the families of the three boys in the car, who had to deal with the death or injuries of loved ones**
   - **the boys who survived the crash had to deal with the loss of their friend**
   - **Colin Robinson, who lost his life**
   - **the friends and teachers in the community who knew the boys**
   - **the family driving the oncoming Honda, who had damage to their vehicle and emotional distress as a result of the accident**

3. Why do you think the state of Oregon requires that new drivers cannot give rides to people outside of their family for the first 90 days they have their licence? What kind of distractions may cause potential problems, especially for new drivers?

   The condition is probably in place so that new drivers can get used to handling a vehicle before adding other people to distract them. Some drivers may talk and not keep their concentration very well. Some new drivers might also feel pressure and stress about the responsibility of having others in the car with them.

   Distractions that can cause problems are

   - **music (adjusting radio stations, volume control, selecting songs, changing CDs)**
   - **company (talking)**
   - **eating and drinking while driving**
   - **applying makeup, fussing with hair**
   - **talking or texting on a cell phone**
   - **looking for something in your purse or console**

Grade 10 Science (20F)

Module 4

Weather Dynamics

This module contains the following:

Module 4: Introduction

Welcome to the fourth and final module in Grade 10 Science!

Weather affects everyone. This module will give you the chance to learn about weather and weather patterns. Knowledge about weather not only helps us plan what to wear and what activities we can do outdoors, it also helps us plan seasonal activities such as when to plant a garden. Understanding weather patterns allows us to predict storms and evacuate areas that may be affected.

Weather is influenced by many factors: our atmosphere, moisture, air pressure, and wind. Some of these factors are local, like living beside a lake or an ocean, while other factors, like prevailing winds, are global. The tilt of Earth and the heat we get from the Sun also influence the weather we experience.

Advances in technology and a better understanding of weather systems provide us with up-to-the-minute information. We know that the climate (long-term patterns of weather) is being altered by natural processes (volcanic eruptions) and by human activities (the release of greenhouse gases due to fossil fuel use, industrial processes, and deforestation).

At the end of this module, you will apply your knowledge of weather and climate in a discussion of the potential consequences of climate change.

Learning Activities

There are several learning activities placed throughout this module, which will help you to 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.

Assignments

When you have completed the assignments for Module 4, submit your completed 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.

Assessment Checklist

- ❑ Lesson 3 Assignment 4.1: Energy Flow
- ❑ Lesson 6 Assignment 4.2: Research Project
- ❑ Lesson 8 Assignment 4.3: Climate Change Discussion

These assignments will be worth a portion of the 60 percent of the total marks you will receive for assignments in this course.

What Will You Need?

In order to complete this module, you will need access to the following:

Required Resources

- Coloured pencils (red, green, light blue, and light brown) are required for Learning Activity 4.2.

Optional Resources

- A **computer with Internet access** would be beneficial throughout this module, especially to complete research assignments such as Assignment 4.2. It would also help you to access additional information that is provided on websites that are listed throughout the module. All URLs listed in this module were working when this course was written. However, since some Internet sites change or disappear, you might find that some of these sites are no longer available or appropriate. If that happens, you could use a search engine (e.g., google.ca) to find the information that you are looking for.
- A **computer with a word processor like Microsoft Word** would be beneficial to help you complete assignments, including Assignment 4.2 where you will have the option of writing a report.
- A **computer with presentation and slide software like Microsoft PowerPoint** would be beneficial to help you complete assignments including Assignment 4.2 where you will have the option of creating a slide presentation.

- **Access to a library**, such as a public or school library, would be beneficial, especially if you do not have access to a computer with Internet access. Access to a library would help you complete research assignments like Assignment 4.2.

Final Examination

You will write the final examination when you have completed Module 4 of this course. The final examination is based on Modules 3 and 4, and is worth 20 percent of your final mark in this course.

To write the final examination, you will need to apply for it, as described in the course Introduction.

Notes

Lesson 1: Earth's Atmosphere and Hydrosphere

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the makeup and organization of the hydrosphere
- ❑ describe the structure and organization of our layered atmosphere, including the troposphere and stratosphere

Key Words

- Earth's atmospheric gases: oxygen, nitrogen, argon, carbon dioxide, methane, water vapour
- troposphere
- stratosphere
- ozone
- salt water
- fresh water
- polar ice caps/glaciers

Introduction

This first lesson will re-introduce you to the water (hydrological) cycle, global distribution of salt and fresh water, and world maps (continents and oceans, latitude and longitude), and will review some basics of weather you may have covered in previous grades.

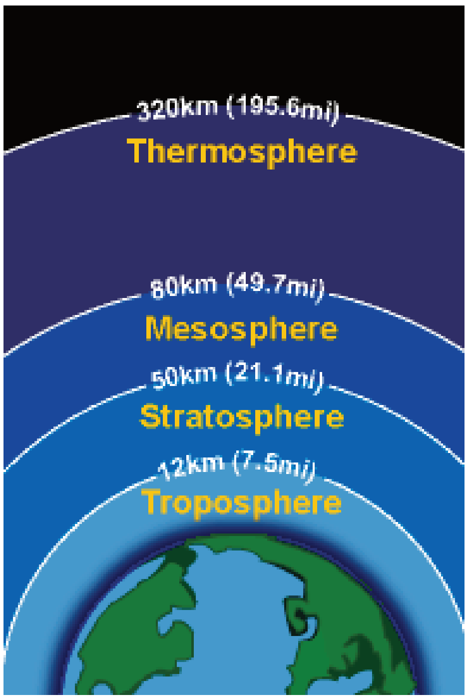
Weather

Weather can be defined as the condition of the atmosphere (the air that surrounds us) at a particular time and place. Is it sunny? Is it cloudy? Is it warm? Is it cold? Is it windy? Is it calm? Is it snowing? Is it raining?

The **atmosphere** and **hydrosphere** (all of Earth's water) of our home planet are its most unique and important features. Without them, life on Earth would be impossible. It is no surprise that our weather depends on the conditions in the atmosphere (after all, that's where weather occurs), and on interactions with water in the hydrosphere.

Atmosphere

While there are several layers of the **atmosphere** above Earth's surface, the **troposphere** and the **stratosphere** are responsible for our weather systems.



Source: Environmental Protection Agency. "Atmosphere." *Air Pollution Control Orientation Course*. 29 Jan. 2010. www.epa.gov/apti/course422/ap1.html (20 Apr. 2012). Reproduced with permission.

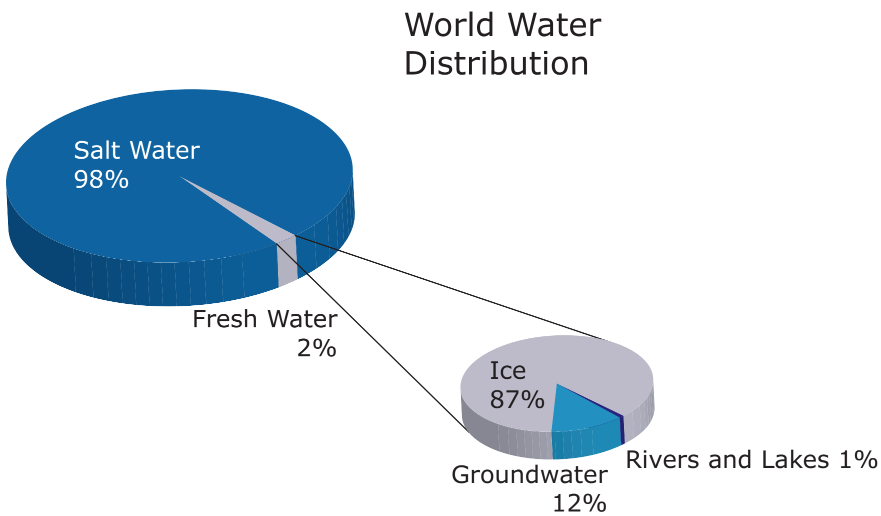
The layer of air that lies closest to the surface of Earth is called the **troposphere**. It is in this layer that our weather occurs. The gases present in the air near Earth's surface are nitrogen (78%), oxygen (21%), and other gases (1%), such as water vapour, argon, and carbon dioxide.

The **stratosphere** lies above the troposphere and contains the ozone layer. **Ozone** is a compound made up of three oxygen atoms (the molecular formula for ozone gas is O_3), which shields us against the Sun's ultraviolet rays.

Hydrosphere

The **hydrosphere** is made up of salt water, fresh water, and polar icecaps and glaciers—the largest part being salt water. Earth's oceans hold just over 97 percent of Earth's water, most of it as salt water. (Icebergs are chunks of freshwater ice that are floating and melting in the oceans, like Earth's great ice cubes.)

Canada has a large amount of fresh water in its lakes, rivers, and glaciers. We have almost 10 percent of the world's freshwater supply.



Reference: University of Nebraska-Lincoln. School of Natural Resources. "World Water Distribution." *Real-Time Groundwater Level Monitoring Network*. 2007. http://snr-1349.unl.edu/navigation/waterdistribution.aspx (20 Apr. 2012).

A final component to the hydrosphere is the **water vapour** that is present in the atmosphere. (And yes, this means our definitions of hydrosphere and atmosphere blend with one another when it comes to water vapour.) This accounts for approximately 0.001 to 0.002 percent of Earth's water. Yet, it is this **very** small fraction of the hydrosphere that weather forecasters are always talking about.

Learning Activity 4.1: Comparing and Contrasting the Atmosphere and Hydrosphere

1. Complete the following Compare and Contrast frame for the terms *atmosphere* and *hydrosphere*.

Compare and Contrast

C
O
M
P
A
R
E

How are atmosphere and hydrosphere alike?

continued

C O N T R A S T

How are atmosphere and hydrosphere different?

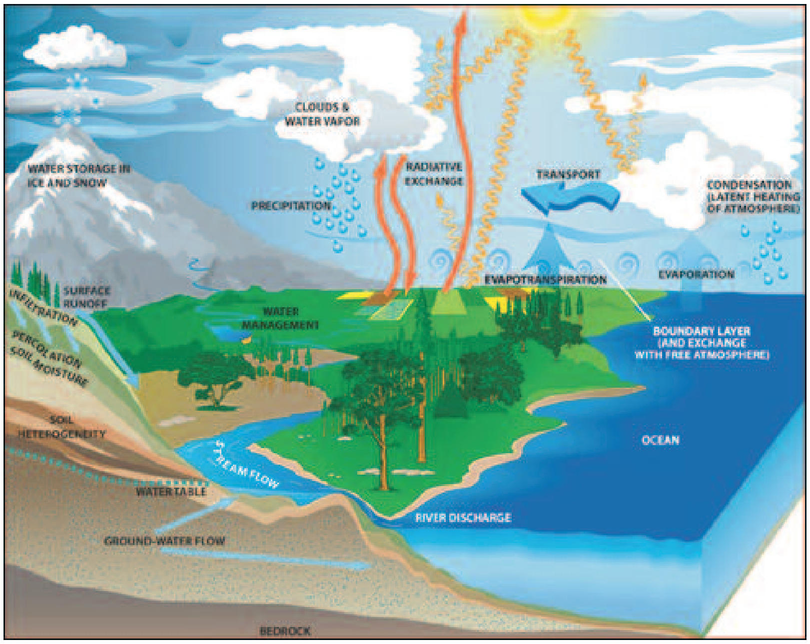
Write a statement to compare and contrast the two terms, concepts, or events.

Compare and Contrast Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Check the Learning Activity Answer Key found at the end of this module.

Water Cycle

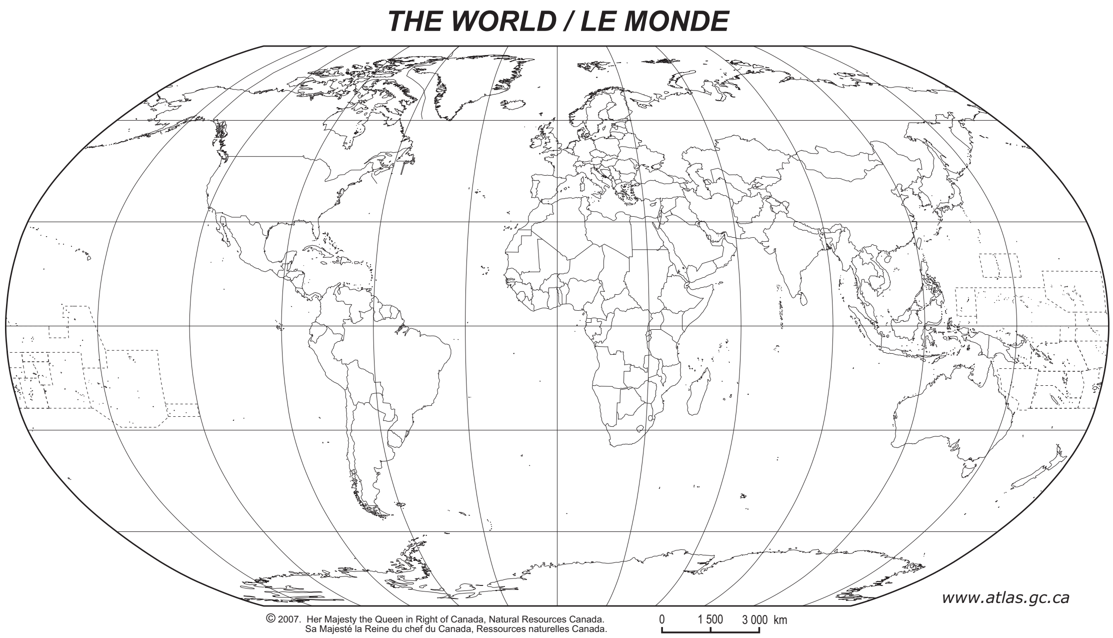
Because so much of Earth's surface is covered by water, weather systems are greatly affected by the hydrosphere. Water moves into, out of, and through the atmosphere in a continuous process called the water (hydrological) cycle.



Source: National Aeronautics and Space Administration (NASA). "Media Library." *NASA Science*. http://science.nasa.gov/media/medialibrary/2010/03/31/water_cycle.jpg (3 Mar. 2012). Reproduced with permission.

Heat from the Sun causes water to evaporate (change from a liquid to a vapour) or ice to sublime (change from a solid to a vapour). This invisible water vapour rises. Eventually, the rising water vapour cools down and condenses (changes from vapour to liquid) into fog, mist, and clouds. The condensing water vapour can even change into ice crystals. The resulting precipitation falls to the ground as rain or snow and the cycle starts again.

In the last part of Lesson 1, you will review the location of the continents and oceans as well as the major lines of longitude and latitude. In Lesson 2, you will learn about the factors that influence how much of the Sun's energy is absorbed by Earth's surface and the atmosphere, and how much is reflected by Earth's surface and the atmosphere. The following map of Earth will be a useful reference for you.



Source: Natural Resources Canada. "The World." *The Atlas of Canada*. 7 May 2007. http://atlas.nrcan.gc.ca/site/english/maps/reference/outlineworld/world01 (20 Apr. 2012). Reproduced with permission. This reproduction is a copy of an official work that is published by the Government of Canada, and the reproduction has not been produced in affiliation with, or with the endorsement of, the Government of Canada.

Locate the equator as well as the Tropics of Cancer and Capricorn. Which continents lie above the equator and below the equator?

The ice caps that cover Antarctica and the northern Arctic region, as well as the various glaciers, together make up almost 2 percent of Earth's water. If these were to melt, they would add enough water to the oceans to cause massive coastal flooding (a great number of cities are next to or close to sea level). Looking at the map of the world, which countries do you think would be most affected? Later on in this module, we will be looking at the risks to society if global warming were to cause the disappearance of all the polar ice.

Summary

Our weather depends on the conditions in the atmosphere and on interactions with water in the hydrosphere.

The troposphere lies closest to the surface of Earth and contains the gases present in the air. The stratosphere lies above the troposphere and contains the ozone layer.

The hydrosphere is made up of salt water, fresh water, and polar ice caps and glaciers. Water vapour is present in both the atmosphere and the hydrosphere. Water moves into, out of, and through the atmosphere in a continuous process called the water (hydrological) cycle.

In the next lesson you will learn about what happens to the Sun's energy when it encounters Earth's atmosphere.

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the factors that control incoming and outgoing radiation in Earth's atmosphere
- ❑ understand how albedo (surface reflectance) affects the amount of solar radiation reaching Earth's surface

Key Words

- solar radiation budget
- absorption
- reflection
- Earth's axial tilt
- albedo

Introduction

In this lesson, you will get a summary of how the Sun's energy behaves when it encounters Earth's atmosphere, oceans, continents, and ice caps. The heat and light that make things happen on Earth come from the Sun. The weather we experience is not a result of a set of random acts of nature, but a response to the unequal heating of Earth's atmosphere.

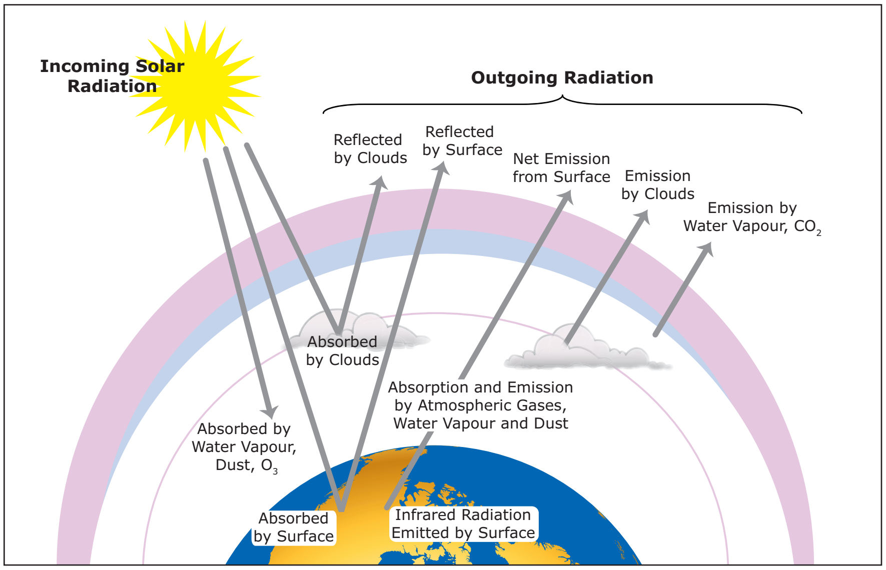
The Sun's Energy (Solar Radiation)

The Sun not only warms Earth and plays an important role in our daily weather, it is also responsible for creating the wind systems that are found on our planet. Unbalanced rates of heating and cooling from one place to another within the atmosphere create temperature gradients (a range from high to low temperatures). As a result the atmosphere circulates, and heat energy is redistributed.

The Sun's energy travels through space with little interference until it reaches Earth's atmosphere. Much of the Sun's energy is absorbed by gases, dust particles, clouds, and Earth's surface, while the rest is reflected.

Earth's Energy Budget: Painting a Picture of Reflectance/Absorption

The amount of energy that Earth receives can be thought of as a budget or an allowance. Earth's total energy budget can be represented as a diagram showing various percentages for incoming and outgoing radiation and heat transfers. If 100 units of incoming solar radiation reached Earth, 19 units would be absorbed by the atmosphere and clouds. Fifty-one units would be absorbed by Earth's surface and the remaining 30 units would be reflected and scattered by the atmosphere, clouds, and Earth's surface.

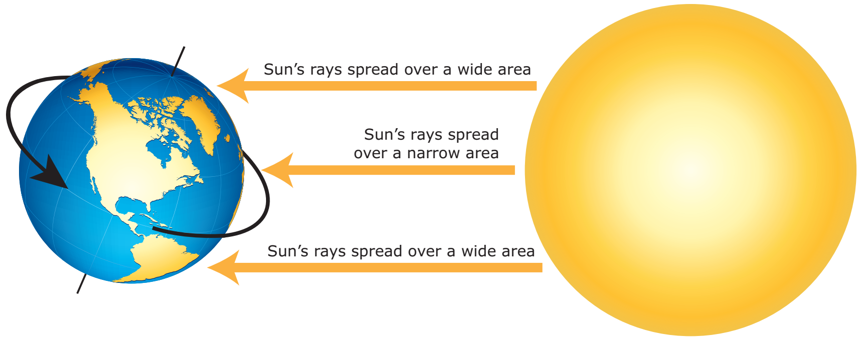


Reference: National Aeronautics and Space Administration (NASA). "The Earth's energy balance diagram." *Earth's Radiation Budget Facts*. http://science-edu.larc.nasa.gov/EDDOCS/radiation_facts.html (23 Apr. 2012).

Earth's atmosphere is heated by incoming energy from the sun (solar radiation) **and** by the solar radiation that is reflected from Earth's surface. However, this energy is not evenly distributed due to the tilt of Earth's axis.

Earth's Axial Tilt

The 23.5 degree tilt in Earth's axis causes a maximum amount of solar radiation to hit the Northern Hemisphere (area above the equator) during the middle months of the year (April to September) and the Southern Hemisphere (area below the equator) during the beginning and ending of the year.



In addition, the curve of Earth’s surface affects the way that solar energy is distributed. At the equator, the Sun’s rays hit a smaller surface area directly whereas the rays hitting near the poles are slanted and transfer less heat because the rays are spread over a much larger area.

Not all of the Sun’s radiation reaches Earth. Some radiation is absorbed, scattered, or reflected by the atmosphere. Radiation can also be absorbed by water vapour, ozone, and dust particles, scattered by air molecules, and reflected by clouds.

The solar radiation reaching the ground can be reflected or absorbed. Some land materials like rocks, snow, and sand reflect most of the Sun’s radiation, whereas bodies of water like oceans and lakes absorb most of the radiation they receive.

What Is Albedo?

Albedo comes from the Latin word *albus*, meaning “white.” The more reflective a surface is, the higher the albedo. In other words, albedo is a measure of the **surface reflectance**.

Dark soils have a very low albedo. White rocks have a high albedo. Clean, dry snow can reflect between 75 percent and 95 percent of the incoming sunlight. Thin clouds have albedos between 30 to 50 percent whereas thick clouds can range between 60 and 90 percent. Earth’s overall albedo lies between 29 percent and 34 percent. Much of the incoming radiation is reflected back to space by the atmosphere, clouds, snow, oceans, and ground.

Oceans and bodies of water are heat sinks (they absorb and hold radiant energy), that can slowly release the heat they have captured from the Sun. Snow-covered areas hold on to very little of the Sun’s heat and have colder local conditions. Dirty, darkened snow will melt much more quickly because of its lower albedo, which then also allows the underlying ground to warm up more quickly.

Obviously, albedo in any one location will vary from day to day and season to season according to the cloud cover in the sky, the snow cover, and even the vegetation cover. However, albedo is not the only factor that will determine temperature conditions in a certain location. After all, the Sahara is very warm in daytime in spite of its reflectivity, and northern oceans remain cool despite their high absorption of solar energy.

Learning Activity 4.2: Colour Coding Earth's Surface

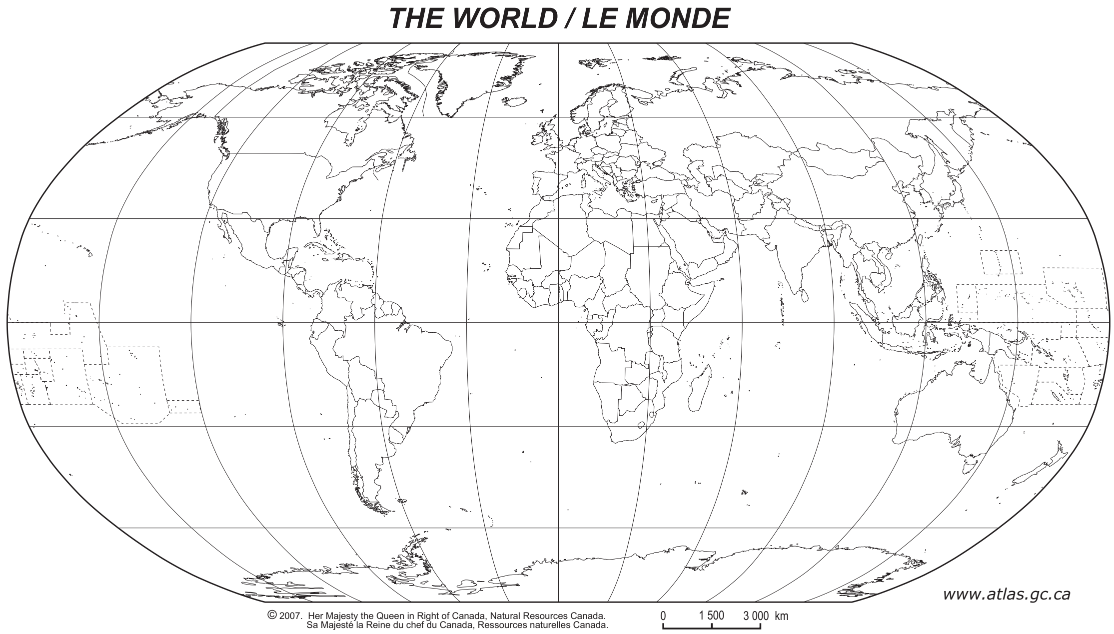
The following graphic shows Earth's surface (oceans and continents), including areas that are snow-covered in winter and major desert areas. Fill in the oceans in red (since they retain most of the incoming solar energy), the snow-covered areas in light blue (since they simply reflect most of the Sun's rays), the deserts in light brown, and the other continental areas in green.

How different does Earth look now?

Identify the areas that have a high albedo (high reflectance) and a low albedo (low reflectance).

continued

Learning Activity 4.2 (continued)



Source: Natural Resources Canada. "The World." *The Atlas of Canada*. 7 May 2007. http://atlas.nrcan.gc.ca/site/english/maps/reference/outlineworld/world01 (20 Apr. 2012). Reproduced with permission. This reproduction is a copy of an official work that is published by the Government of Canada, and the reproduction has not been produced in affiliation with, or with the endorsement of, the Government of Canada.

Check the Learning Activity Answer Key found at the end of this module.

Summary

The weather we experience is not a result of a set of random acts of nature, but a response to the unequal heating of Earth's atmosphere. As a result the atmosphere circulates and heat energy is redistributed.

Much of the Sun's energy is absorbed by gases, dust particles, clouds, and Earth's surface, while the rest is reflected.

Incoming energy is not evenly distributed due to the tilt of Earth's axis and the curve of Earth's surface.

The solar radiation reaching the ground can be reflected or absorbed. Some land materials like rocks, snow, and sand reflect most of the Sun's radiation, whereas bodies of water like oceans and lakes absorb most of the radiation they receive.

In the next lesson you will learn how wind and ocean currents develop.

Lesson 3: Energy Flow

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the effects of heat transfer within the atmosphere and hydrosphere
- ❑ explain how heat transfer results in the development and movement of wind and ocean currents
- ❑ understand how the Coriolis effect works

Key Words

- convection
- conduction
- latent heat energy
- Coriolis effect
- jet stream

Introduction

In the last lesson you learned how the Sun's energy behaves when it encounters Earth's atmosphere, oceans, continents, and ice caps.

The Sun not only warms Earth, but it is also responsible for creating the wind systems that are found on our planet. In this lesson you will explore the effects of heat transfer within the atmosphere and hydrosphere and the development and movement of wind and ocean currents.

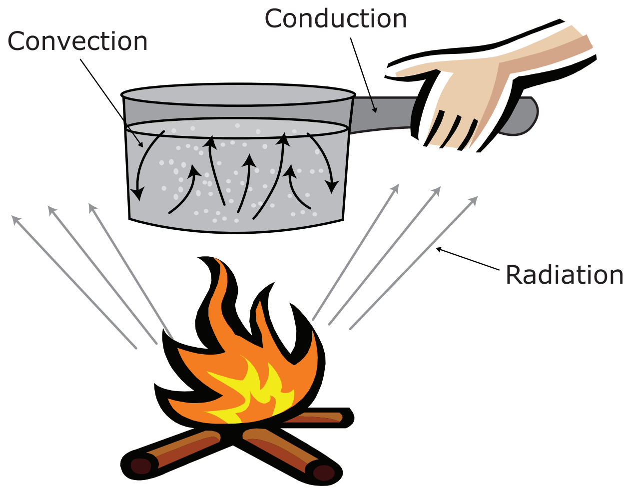
Heat Transfer within the Atmosphere

The transfer of heat in Earth's atmosphere happens in three different ways:

- through **conduction**—the transfer of energy through contact
- through **convection**—the transfer of energy through the movement of particles in a gas or liquid

- through **latent heating**—the energy necessary for a change of state

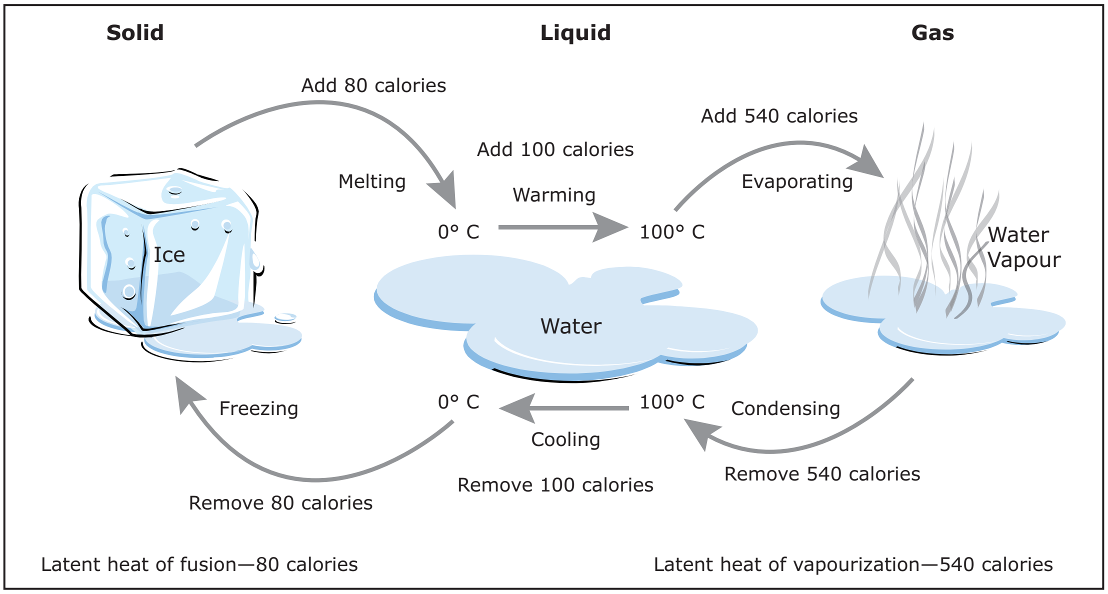
Conduction involves the transfer of heat energy from a warmer object to a cooler one through direct contact. When you place a pot on a hot stove element, the pot gets hot. Within the atmosphere, conduction happens only in the very thin layer of air that is in immediate contact with Earth's surface.



Convection involves the movement of particles in a liquid or a gas and is an important process in atmospheric heating. Convection happens because pockets of air with differing temperatures have different densities. As air above Earth's surface warms, it becomes less dense and rises. As warm air rises it cools, becoming more dense until it sinks. Cooler and denser air tends to sink and fall. As warm air rises it is replaced by cooler air underneath. This cooler air may, in turn, be warmed by the surface, become less dense and rise, repeating the process. Convection currents are created through this process of heating and cooling.

These differences in air temperature and density create worldwide movements of air, and global wind patterns can develop. Having a spinning planet with the right amount of spin is also very important. On Earth we have very well developed and constant global wind belts. One important example is the **jet streams**. These are high-speed winds in the upper regions of the troposphere, often around the mid-latitudes. They tend to move from west to east and steer most of the major weather systems, such as low-pressure and high-pressure systems.

Latent heat is the heat energy released or absorbed when a substance changes phase or state: from solid to liquid, liquid to gas, gas to liquid, and so on. As the heat from the Sun causes water on Earth's surface to evaporate, latent heat from the phase change (liquid to gas), is stored in the water vapour. As air containing the water vapour is warmed by Earth's surface through conduction and convection, it rises, carrying the water vapour with it. As the air rises and cools it becomes saturated and some of the water vapour condenses into water droplets. This change of phase releases the stored latent heat into the atmosphere, where it warms the surrounding air further, and causes it to rise more. The process of latent heat builds on the process of conduction and convection and allows much heat energy to be transferred from Earth's surface into its atmosphere.

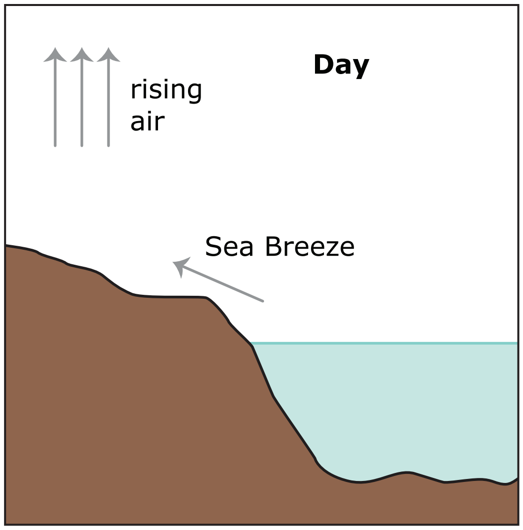


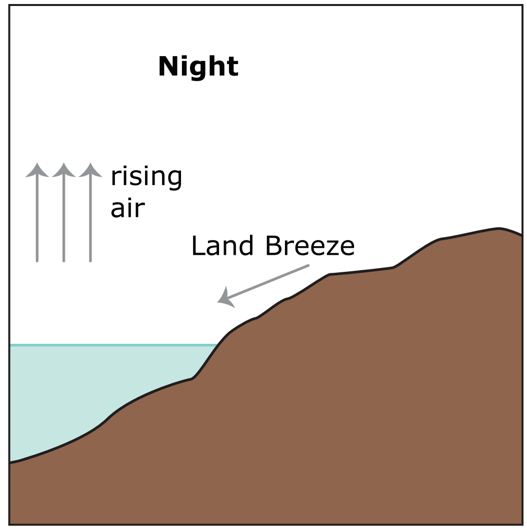
Reference: Portland Waldorf High School. "Latent Heat." *Thermodynamics*. 2008. www.alchemical.org/thermo/latentheat.html (23 Apr. 2012).

Local and Global Effects of Heat Transfer

As you learned earlier, the heating of Earth's surface is uneven, which results in air moving and circulating in an attempt to even out the heat distribution. This motion causes winds. From the slightest breeze to a raging hurricane, differences in temperature are responsible for producing wind.

The sea breeze/land breeze system that develops at a seashore or lakeshore is an example of a local wind system. Bodies of water change temperature more slowly than land masses do. The land along the lakeshore heats faster than the nearby water. During the day, the air over land tends to be warmer and has a lower density than the air over the water. The warm air rises and the cooler air above the water moves in under the warm air to replace it. This is how a sea breeze forms. At night, the land cools faster than the water, with the air above the land becoming cooler and more dense. The warm air over the water rises, and a land breeze results as the cool air moves toward the water.





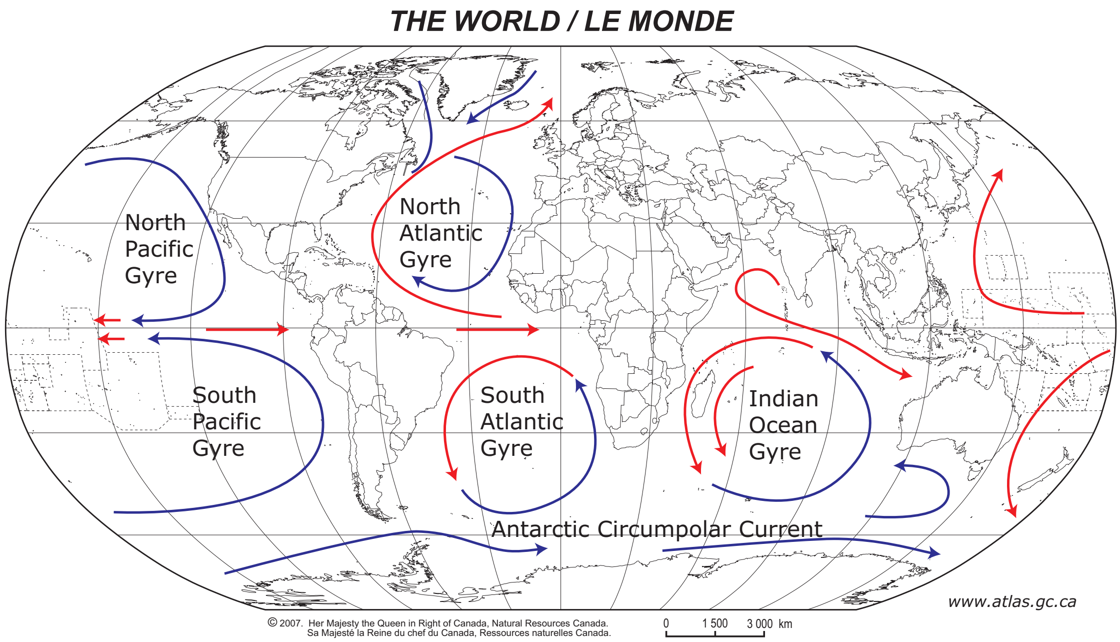
Global patterns of air motion develop in the same way in the atmosphere. Heat from the warmer areas of Earth's surface is distributed throughout the globe by winds and deep ocean currents.

Deep water ocean currents slowly circulate cold water along the bottom of the ocean in a direction from the poles to the equator. Along the surface, warm water moves from the equator to the poles. These movements create convection currents in the oceans.

Warm and moist air from the areas around the equator rises while cool and dry air from the poles sinks and moves underneath the rising warm air. This produces a global wind pattern. Earth's rotation deflects winds and ocean currents to the right from the equator, in the Northern Hemisphere and to the left from the equator, in the Southern Hemisphere. This deflection is called the **Coriolis effect**.

The influence of Earth's rotation on air, or any object moving on Earth's surface, is called the Coriolis effect. As you move away from the equator, each point on Earth rotates at different speeds, depending on the latitude. For example, at the equator, the speed of rotation at Earth's surface is 1664 kilometres per hour. At 30 degrees north latitude, the speed is 1392 kilometres per hour and at 45 degrees north latitude, the speed drops to 1168 kilometres per hour.

There are many examples of movement along curved paths in Earth's atmosphere and oceans. Near-surface winds spiral into low-pressure areas and out of high-pressure areas. Ocean currents flow in huge, almost circular patterns (called "gyres") that are thousands of kilometres across.



Source: Natural Resources Canada. "The World." *The Atlas of Canada*. 7 May 2007. http://atlas.nrcan.gc.ca/site/english/maps/reference/outlineworld/world01 (20 Apr. 2012). Adapted with permission of Natural Resources Canada 2012, courtesy of the Atlas of Canada.

All motion must be measured with respect to something, and Earth is our frame of reference. Earth is so large that we usually think of it as being unmoving. That is why objects moving horizontally and freely appear to turn to the right or left. Actually, it is Earth that is doing the turning underneath as the object moves forward.

Learning Activity 4.3: Because Earth Turns*

Introduction

Almost everywhere on Earth (except at the equator), objects that move horizontally and freely (unconstrained) across Earth's surface travel in curved paths. Objects such as planes, boats, bullets, air parcels, and water parcels turn right or left as seen from our vantage point on Earth. This activity investigates the reason for this turning, a phenomenon known as the Coriolis effect.

continued

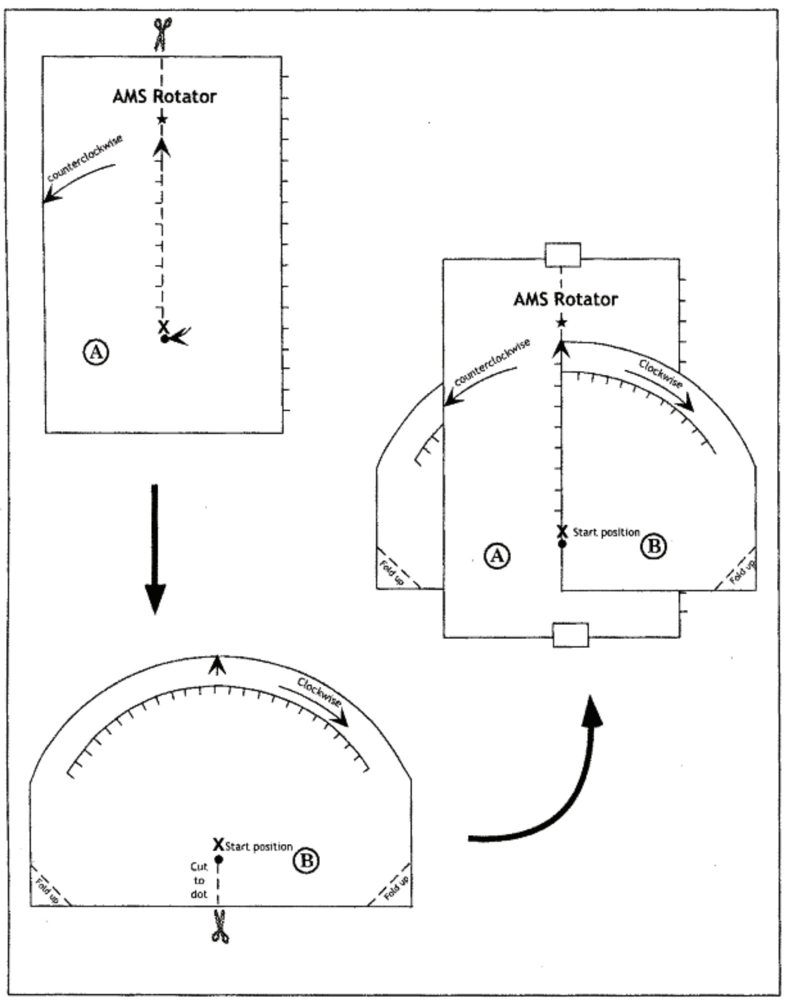
* With the exception of the Directions below, this learning activity consists of excerpts from the following source: Environment Canada. "Module 4: The Coriolis Effect." *Project Atmosphere Canada*. 2001. www.cmos.ca/ProjectAtmosphere/module4_the_coriolis_effect_e.html (23 Apr. 2012). ©Her Majesty the Queen in Right of Canada, 2001. Reproduced with permission.

Directions

The diagram and directions that follow should assist you in making the **AMS Rotator**. AMS stands for the American Meteorological Society, a group that is similar to Environment Canada.

1. Put the **AMS Rotator** device together as shown in and explained on the diagrams.
2. Lay the AMS Rotator flat on the desk in front of you. Now tape A to your desk at the two places shown, insert B, and make sure that B can rotate freely.
3. Fold up the bottom two corners of B as directed. Gripping these tabs, practise rotating B so that the two dots (marked "Start position") are always together.

A straight scale is drawn along the edge of A, and a curved scale is drawn along B.



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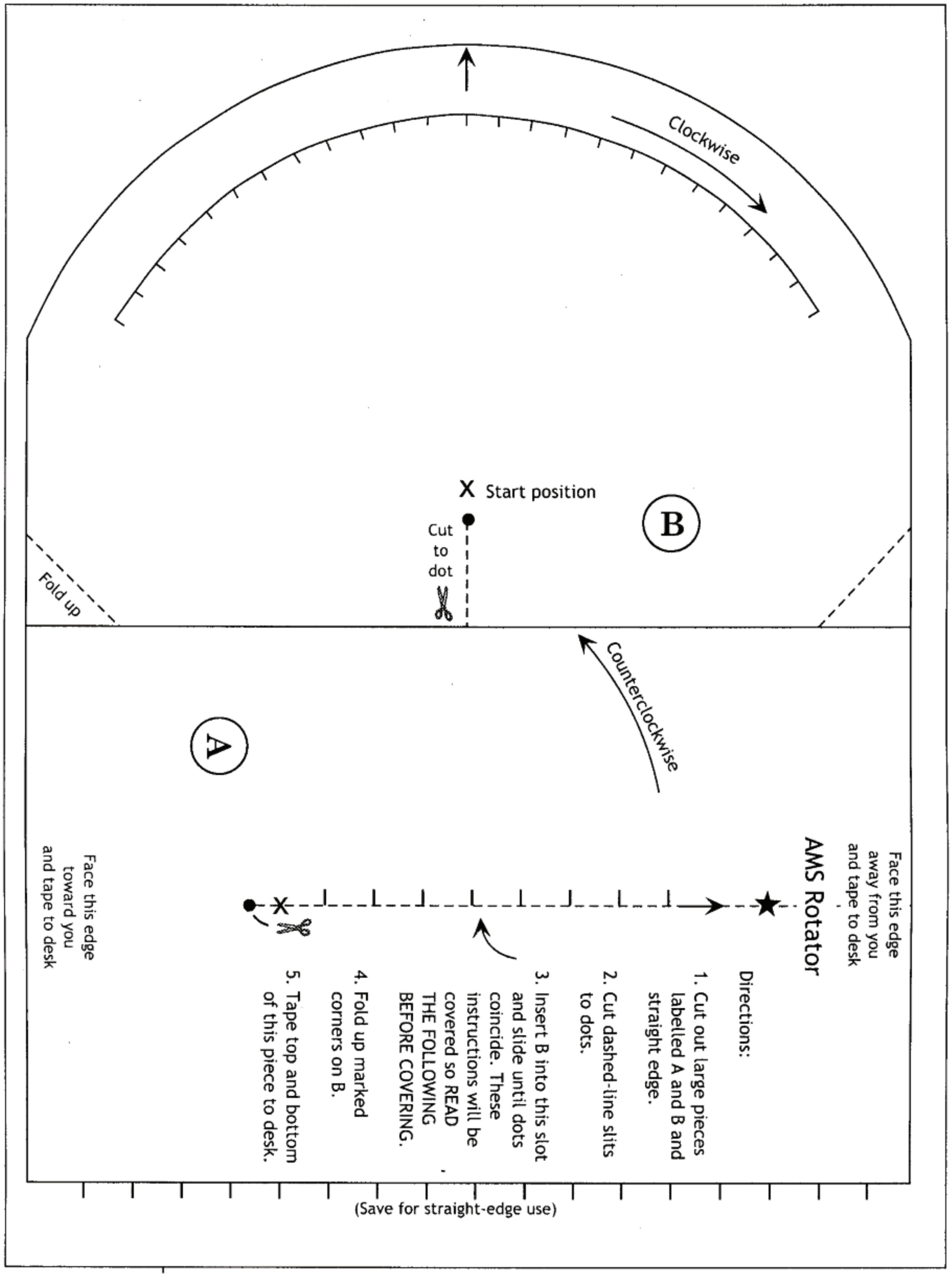
Learning Activity 4.3 (continued)



continued

Notes

Learning Activity 4.3 (continued)

Investigations

Where options are contained in [brackets], CIRCLE the response that you believe is the correct one.

1. Orient B in the "cross" position as shown in the drawing. If positioned properly, a straight arrow should point towards the ★. Place your pencil point at the centre of the Start Position X. Carefully draw a line on B along the cut-edge and directly towards the ★. The line you drew represents a path that is **[(straight) (curved)]**.
2. Now investigate how rotation affects the path of your pencil lines. Again begin with B in the "cross" position with the direction arrow pointing towards the ★. Pulling the lower left tab towards you, rotate B counter-clockwise through one division of the curved scale (on B). Make a pencil dot on B along the straight scale at one scale division above the Start Position X. Continue rotating B counter-clockwise one division at a time along the curved scale, stopping each time to mark a pencil dot on B at each successive division along the straight scale. Repeat these steps until you reach the curved scale. Starting at X, connect the dots with a smooth curve. Place an arrowhead at the end of the line to show the direction of the motion. The line you drew on B is **[(straight) (curved)]**.
3. You actually moved the pencil point along a path that was both straight and curved at the same time! This is possible because motion is measured relative to a frame of reference. (Familiar frames of reference are east-west, north-south, up-down.) In this activity, you were using two different frames of reference, one fixed and the other rotating. When the pencil-point motion was observed relative to the fixed A and ★, its path was **[(straight) (curved)]**. When the pencil motion was measured relative to B, which was rotating, the path was **[(straight) (curved)]**.
4. Begin again with B in the "cross" position and the arrow pointing towards the ★. Pulling the lower right tab towards you, rotate B clockwise one division of the curved scale and make a pencil dot on B along the straight scale at one scale division above the Start Position X. Continue in similar fashion as you did in Item 2 to determine the path of the moving pencil point. The path was straight when the pencil-point motion was observed relative to **[(A) (B)]**. The path was curved when the pencil motion was measured relative to **[(A) (B)]**.

continued

Learning Activity 4.3 (continued)

5. Imagine yourself shrunk down in size, located at X, and looking towards the ★. You observe all three situations described above (that is, no motion of B, counter-clockwise rotation, and clockwise rotation). From your perspective at the X starting position, in all three cases the pencil point moved towards the ★ along a **[(straight) (curved)]** path.
6. Watching the same motion on B, the pencil path was straight in the absence of any rotation. However, the pencil path curved to the **[(right) (left)]** when B rotated counter-clockwise. When the rotation was clockwise, the pencil path curved to the **[(right) (left)]**. This apparent deflection of motion from a straight line in a rotating coordinate system is called the Coriolis effect for Gaspard Gustave de Coriolis (1792–1843) who first explained it mathematically. Because Earth rotates, objects moving freely across its surface, except at the equator, exhibit curved paths.
7. Imagine yourself far above the North Pole, looking down on Earth below. Think of B in the AMS Rotator as representing Earth. As seen against the background stars, Earth rotates in a counter-clockwise direction. From your perspective, an object moving freely across Earth's surface would move along a **[(straight) (curved)]** path relative to the background stars (depicted by the ★ on the AMS Rotator). Now think of yourself on Earth's surface at the North Pole at the dot position while watching the same motion. From this perspective, you observe the object's motion relative to Earth's surface. You see the object moving along a path that **[(is straight) (curves to the right) (curves to the left)]**.
8. Imagine yourself located far above the South Pole. As seen against the background stars, Earth rotates in a clockwise direction. The sense of rotation is reversed from that at the North Pole because you are now looking at Earth from the opposite direction. An object moving freely across Earth's surface is observed to move along a **[(straight) (curved)]** path relative to the background stars. Now think of yourself on Earth's surface at the South Pole while watching the same motion. From this perspective, you observe the object's motion relative to Earth's surface. You see the object moving along a path that **[(is straight) (curves to the right) (curves to the left)]**.
9. In summary, the Coriolis effect causes objects freely moving horizontally over Earth's surface to curve to the **[(right) (left)]** in the Northern Hemisphere and to curve to the **[(right) (left)]** in the Southern Hemisphere.

Check the Learning Activity Answer Key found at the end of this module.

Summary

The transfer of heat in Earth's atmosphere happens in different ways: through conduction, convection, and latent heating.

Within the atmosphere, conduction happens only in the very thin layer of air that is in immediate contact with Earth's surface. Convection happens because there are density differences in pockets of air with differing temperatures. The process of latent heat builds on the process of conduction and convection and allows much heat energy to be transferred from Earth's surface into its atmosphere.

As you learned earlier, the heating of Earth's surface is uneven, which results in air moving and circulating in an attempt to even out the heat distribution. This motion causes winds.

Earth's rotation deflects winds and ocean currents to the right from the equator in the Northern Hemisphere and to the left from the equator in the Southern Hemisphere. This deflection is called the Coriolis effect.

In the next lesson you will learn how severe weather systems develop and how they behave.

Notes

Assignment 4.1: Energy Flow (12 marks)

1. Predict the effect of melting polar ice caps on the albedo of Earth. Explain why you think your prediction is correct. (*2 marks*)

2. Describe the effect of latitude on the absorption of solar radiation. (*2 marks*)

3. Explain why a direct flight from Winnipeg to Calgary usually takes longer than a direct flight from Calgary to Winnipeg. (*2 marks*)

4. Describe how solar energy causes wind currents. (*4 marks*)

continued

Assignment 4.1 (continued)

5. Suggest reasons why winters in Iceland and Norway are warmer than in Manitoba with similar latitude among these places. (*2 marks*)

Lesson 4: Forecasting Severe Weather Systems

Lesson Focus

After completing this lesson, you will be able to

- ❑ read and interpret the symbols on a weather map
- ❑ explain how severe weather systems form
- ❑ understand the dynamics of severe weather events

Key Words

- high and low pressure systems
- air mass
- warm and cold fronts
- weather station glyphs (or symbols)
- isobars
- isotherms
- humidity
- dew point
- tornadoes
- hurricanes
- extreme temperature events
- cyclones
- thunderstorms
- jet stream
- blizzards

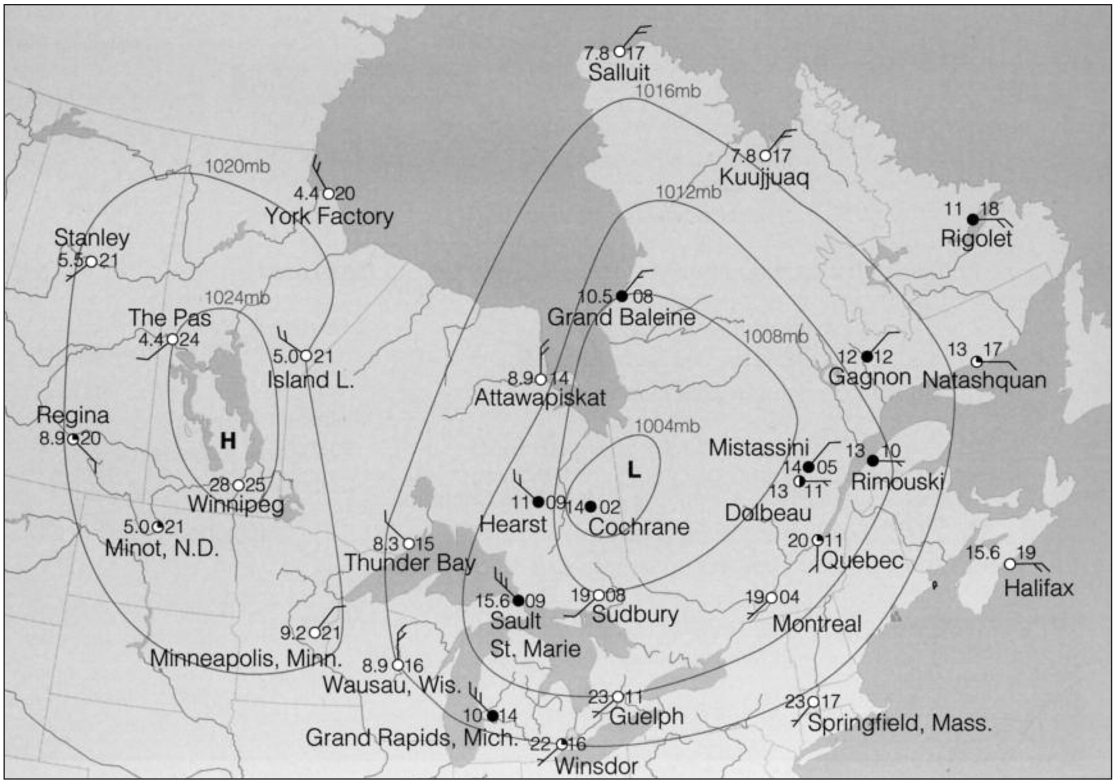
Introduction

In the last lesson you learned how heat energy is transferred in our atmosphere and how the transfer of heat energy results in the creation of winds. In this lesson you will continue to explore how the transfer of heat energy creates differences in pressure and how the change in pressure can result in severe weather events. To start this lesson you will review weather forecasting terms and symbols.

Interpreting Weather Maps

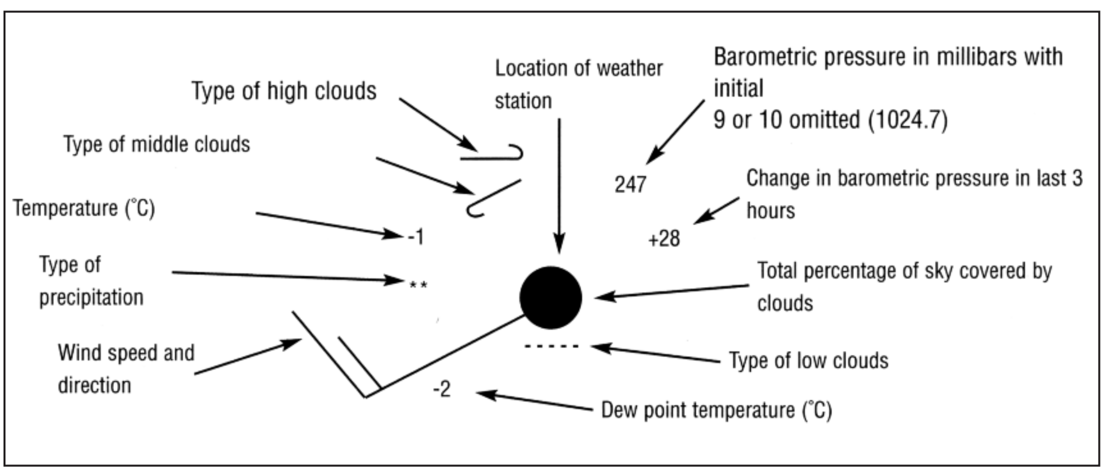
Weather maps are made by combining meteorological data (information about the atmosphere, especially weather and weather conditions) collected from stations all over the country or the world. Weather stations are maintained at airports, broadcasting stations, and some schools, by private citizens and by Environment Canada.

Weather maps usually have an outline of the area being surveyed, the names of the cities where the reporting stations are located, and symbols that represent the weather data. If you combine information from many stations on a map, the map will give you a picture of the large weather systems across the country.



Source: Grace, Eric, et al. Figure 16.16 B. *Sciencepower 10: Science, Technology, Society, Environment*. Toronto, ON: McGraw-Hill Ryerson Limited, 2000. 534. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

A **weather station symbol (glyph)** provides information about the atmospheric pressure, wind speed and direction, cloud cover, temperature, current weather conditions, and dew point of an exact location.

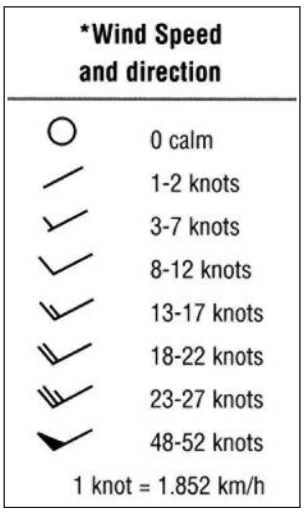


Source: Grace, Eric, et al. "Weather Map Symbols: Sample Plotted Report at Each Station." *Sciencepower 10: Science, Technology, Society, Environment*. Toronto, ON: McGraw-Hill Ryerson Limited, 2000. 576. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

Atmospheric pressure is the force exerted on an object or person by the weight of the air above it. You may not have realized that air has weight.

The force of gravity pulls molecules and particles in the atmosphere toward the centre of Earth. The resulting weight of the air pushing down on itself and on the surface of the planet creates atmospheric pressure.

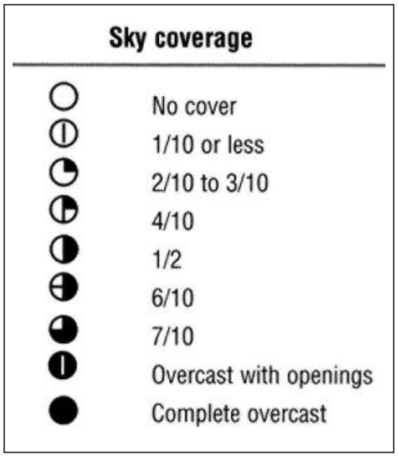
In Canada, the unit of atmospheric pressure most often heard on weather broadcasts is the **kilopascal (kPa)**. The average pressure exerted by the atmosphere at sea level is one kilogram per square centimetre or 101.325 kPa. Often weather maps have curved lines called **isobars**. These lines are drawn to connect locations on the map with the same atmospheric pressure. The highs and lows (or the **H** and **L** symbols) on weather maps represent the centres of large regions of relatively high or low surface air pressure. Highs bring pleasant weather while low pressure systems bring clouds and stormy weather.



Wind speed is measured in knots and shown by the small lines that look like barbs. Each full line represents approximately 10 knots (1 knot = 1.852 km/h) of wind speed. Shorter lines represent wind speeds of approximately 5 knots. Adding the lines (10 + 5) gives you the total wind speed.

Wind direction: If you think of the wind speed lines as the feathers on an arrow, the circle represents the arrowhead. The arrow points in the direction that the wind is blowing, **but** wind direction is designated as the direction the wind is blowing from. If an arrow points to the southeast, the wind direction is called "from the northwest."

Source: Grace, Eric, et al. "Weather Map Symbols: Symbols Used in Plotting Report." *Sciencepower 10: Science, Technology, Society, Environment*. Toronto, ON: McGraw-Hill Ryerson Limited, 2000. 576. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff.*



Cloud cover is shown by the amount of the circle that is blackened. If the circle is not blackened then the skies would be "clear."

Source: Grace, Eric, et al. "Weather Map Symbols: Symbols Used in Plotting Report." *Sciencepower 10: Science, Technology, Society, Environment*. Toronto, ON: McGraw-Hill Ryerson Limited, 2000. 576. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

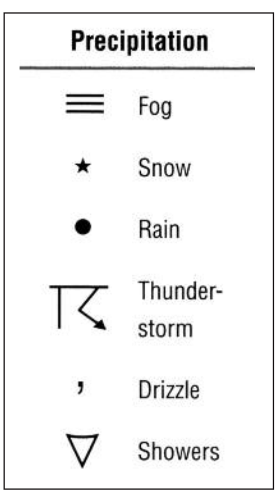
Dew point is the temperature the air would have to be cooled to for the air to become saturated and for water vapour to condense.

The very small amount of water in the atmosphere is necessary for creating Earth's weather systems and climate. Atmospheric heating, humidity, cloud formation, and precipitation are all directly related to the amount of water vapour in the atmosphere.

Warm air can hold much more water than cool air. **Humidity** is a measure of the amount of moisture (water vapour) in the air. It is reported as a percentage for a given temperature (relative humidity).

When air holds all the water vapour it can, we say that the air is saturated and the relative humidity is 100 percent. If warm, unsaturated air is cooled, it will in time reach a temperature where the amount of water vapour already in the air will equal the total amount that the air can hold. At this temperature, the **dew point**, the air becomes saturated and the water vapour will begin to condense to form water droplets, clouds, fog, or dew.

Current weather conditions are shown by the list of symbols below:



Source: Grace, Eric, et al. "Weather Map Symbols: Symbols Used in Plotting Report." *Sciencepower 10: Science, Technology, Society, Environment*. Toronto, ON: McGraw-Hill Ryerson Limited, 2000. 576. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

By combining the information from many stations, an accurate picture of large weather systems can be formed, forecasts can be made, and severe weather can be anticipated.

Temperature in Canada is measured in Celsius degrees (°C) while some other countries use Fahrenheit degrees (°F). Just like weather maps that have curved lines called isobars that connect locations on the map with the same atmospheric pressure, weather maps can also have **isotherms**, which are lines drawn to connect locations on the map with the same temperatures.

Air Masses and Fronts

Air masses are large bodies of air that have different temperatures and relative humidity. When air masses meet they do not mix easily. Warmer air masses rise over cooler air masses, and cooler air masses wedge themselves underneath warmer air masses. This happens because cool air is more dense than warm air.

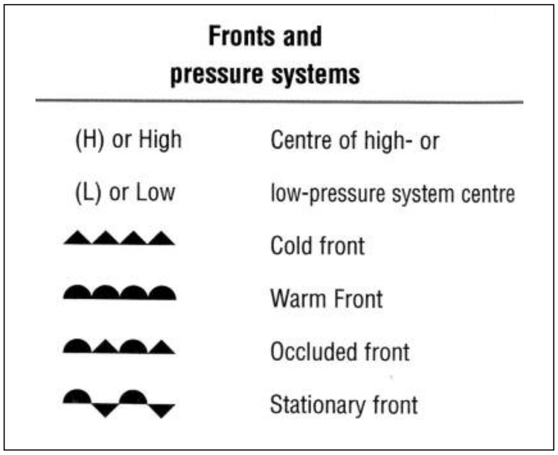
The boundary that forms between warm and cool air masses is called a **front**. There are different types of fronts—the most common ones are cold fronts, warm fronts, and stationary fronts.

Cold front: A cold air mass advances against a warm air mass, forcing the warm air upward. Clouds, precipitation, and sometimes severe weather result during the passage of a cold front. Cooler, dryer air moves into an area after the passage of a cold front.

Warm front: A warm air mass advances against a cold air mass, riding up over the cooler air in front of it. Clouds and precipitation in the form of rain, snow, sleet, or freezing rain can result during the passage of a warm front. Warmer, moist air moves into an area after the passage of a warm front.

Stationary front: A stationary front occurs when neither the cold air mass nor the warm air mass advance against one another. The interaction of warm and cool air along the front is responsible for rain, thunderstorms, and snow.

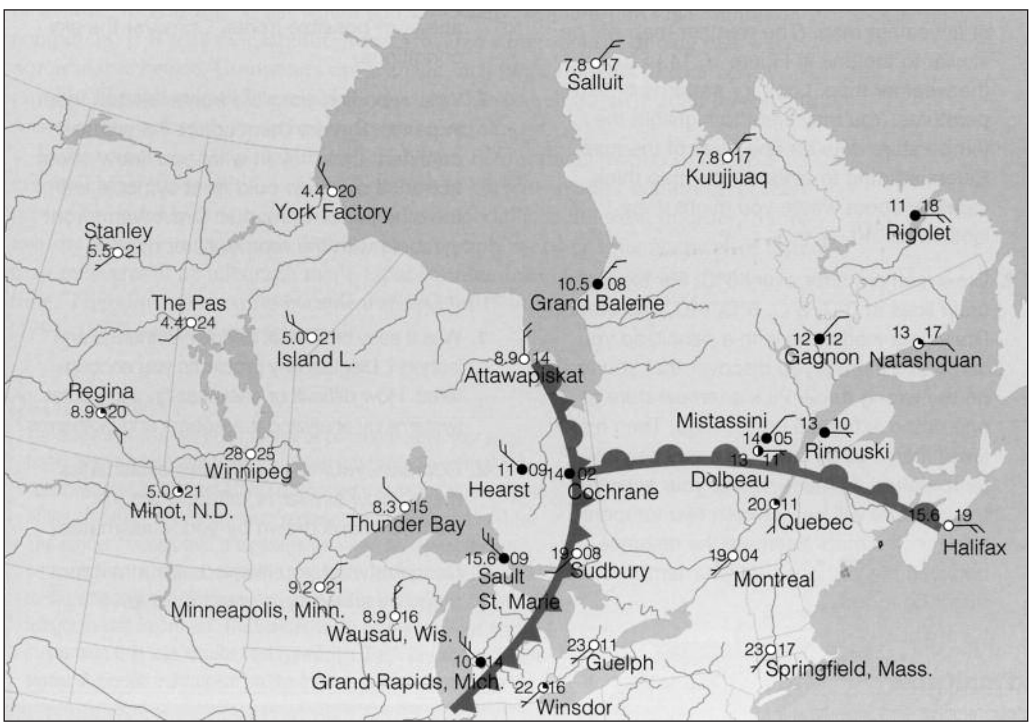
Fronts are responsible for creating clouds, rain, and snow, and are represented by the following symbols on a weather map. The triangles and half-circles point in the direction the front is moving.



Source: Grace, Eric, et al. "Weather Map Symbols: Symbols Used in Plotting Report." *Sciencepower 10: Science, Technology, Society, Environment*. Toronto, ON: McGraw-Hill Ryerson Limited, 2000. 576. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

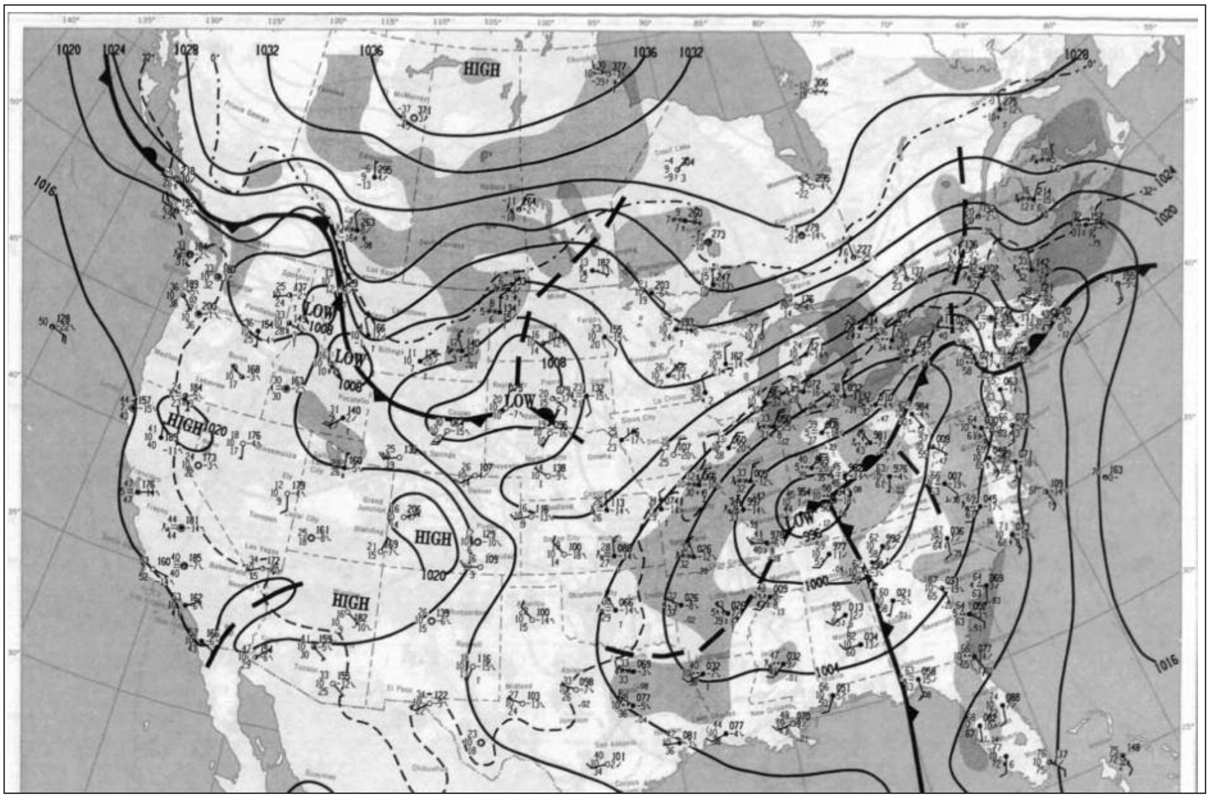
As warmer air comes in contact with colder air and is forced to rise, it expands into the lower pressure found at higher altitudes. This expansion cools the air and the moisture in the air condenses, forming clouds. If the warm air continues to rise and expand, rain or snow may form.

Clouds are a result of the interactions of air masses. Clouds have many patterns, and by looking at cloud types it is possible to predict changes in the weather and the movement of fronts.



Source: Grace, Eric, et al. Figure 16.17. *Sciencepower 10: Science, Technology, Society, Environment*. Toronto, ON: McGraw-Hill Ryerson Limited, 2000. 534. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

Learning Activity 4.4: Reading a Weather Map



Source: National Oceanic and Atmospheric Administration's National Weather Service Forecast Office: Burlington, VT. "Surface observations plot from January 8, 1998." *10th Anniversary of the Devastating 1998 Ice Storm in the Northeast*. 6 Jan. 2008. www.erh.noaa.gov/btv/events/IceStorm1998/ice98.shtml (27 Apr. 2012). Public Domain.

1. Over what area do you find a cold front?
2. What type of front is over the northeastern United States?
3. Locate the areas of high pressure. What do you notice about the isobars around the high pressure areas?
4. Locate the weather glyph near Edmonton.
    a. What is the temperature?
    b. What is the dew point?
    c. What is the cloud cover?
    d. What is the atmospheric pressure?
    e. In what direction is the wind blowing?

continued

Learning Activity 4.4 (continued)

5. Symbols for sky cover have also been included on this chart.
   a. In general, do you find cloudy or clear skies in low-pressure areas?
   b. In high-pressure areas, what occurs with cloud cover?
6. Using the symbols on this map, identify what the weather is like in Churchill (include **percentage of cloud cover**, **temperature**, and **wind direction**).

Check the Learning Activity Answer Key found at the end of this module.

How Severe Weather Systems Develop

Predicting weather changes requires an understanding of how weather systems work. Knowing how severe weather works is important for predicting when it will occur. In this part of Lesson 4 you will learn how thunderstorms, tornadoes, and hurricanes begin.

Severe Thunderstorms

Thunderstorms are something most of us have experienced. They are accompanied by heavy rain, thunder, and lightning. You can recognize one that may be coming by looking at the clouds.

A hot sunny day will cause water vapour from Earth to rise and cool into water droplets. A large amount of water vapour cooling will build up enormous clouds with tightly packed water droplets near the base. If the rising moist air is strong enough, the water vapour gets pushed very high.

Lightning is the result of the rapidly moving cloud particles being rubbed against each other so much that electrical charges occur. The particles become loaded with extra negative charges. When this negatively charged cloud passes over anything that is positively charged the negative charges (electrons) want to leave the cloud and jump to the positively charged object. This jump is called lightning. Lightning can occur from cloud to Earth, cloud to cloud, or even inside a cloud itself.

The big bang (thunder) you hear after lightning occurs is really the air, near the lightning, that has been heated up so fast that it explodes, and the rumbling you hear after is the sound of the thunder bouncing from cloud to cloud.

Thunderstorms that occur with a strong **jet stream** flow (high speed winds in the troposphere that occur around the mid-latitudes) can produce tornadoes.

Tornadoes

Tornadoes look like twisting gray funnels, cylinders, or ropes extending down from a cloud. They are extremely loud and have an intense period of lightning connected with them. Most tornadoes are small, measuring a few hundred metres in diameter and are usually short lived, lasting a minute or two in any one area. However, with wind speeds up to 500 kilometres per hour and extremely low pressures, tornadoes can cause a great deal of damage as they pass.

Tornadoes are usually created when a very cold air front moves into an area where the air is very hot and humid. Most tornadoes form over land in open areas where the land is quickly heated during hot summer days.

Tornadoes are also called twisters and act like vacuum cleaners. When a tornado "touches down," any object it comes in contact with will be sucked up by the tremendous vacuum-like funnel. Since the air pressure inside the tornado is extremely lower than normal, any buildings in its path will be exploded from the inside out as the normal pressure in the building disperses into the low pressure of the tornado.

Tornadoes carry debris for great distances, zigzagging in an unpredictable route across the country.

©Robert Moore. June 22, 2008: Elie Tornado. Used with permission.

Cyclones

Where tornadoes are local severe weather events, **cyclones** are large-scale systems of rotating winds around a central low-pressure area that cover large areas of the ocean or land. Depending on where they form, cyclones are given different names. A **hurricane** is a tropical cyclone that forms in the Atlantic Ocean, Caribbean Sea, Gulf of Mexico, or eastern Pacific. A **typhoon** is a tropical cyclone that forms in the north-western Pacific Ocean. In the Indian Ocean and South Pacific Ocean, these types of storms are just called cyclones.

Hurricanes

Hurricanes are probably the worst type of storm you could experience. Hurricanes that move inland bring heavy rains, strong winds, and flooding. They start over water in low pressure areas where rapidly rising warm, moist air from the ocean cools to form rain. As a result, clouds form and latent heat is released into the atmosphere. The low pressure area causes an increase in the flow of air into the storm. Because of Earth's rotation, the incoming air is deflected (Coriolis effect). The rotating winds evaporate water from the ocean's surface, carrying it into the growing storm system.

Hurricanes are not considered hurricanes until their wind speeds exceed 64 knots or 118 kilometres per hour—below this wind speed the system is considered a tropical storm. Hurricanes have different names in different parts of the world. In Asia they are known as typhoons.

Once the wind speed reaches 118 kilometres per hour, the winds spin so quickly that they are forced into a ring surrounding the central low pressure area. In the central low pressure area called the "eye," the winds are light, and there are few if any clouds and little rain. The eye is surrounded by a thick wall of intense thunderstorms.

As the hurricane and its thunderstorms move over the ocean, the winds create large waves. When the hurricane reaches a coastline, the winds and low pressure also cause a large increase in water level. This unusual rise in sea level is called a storm surge. Storm surges are responsible for the flooding that occurs in low-lying coastal areas.

Hurricanes can last for over a week. Fuelled by warm ocean waters, hurricane season occurs when water temperature is high enough to support the development of a storm system. This usually happens in late summer and early fall. Hurricanes lose their energy as they move over land or cooler water.

Winter Storms

A winter storm is a large weather disturbance connected to a low-pressure system (another type of **cyclone**) that develops along a front during the cooler part of the year. Winter storms can produce strong winds, heavy precipitation (rain, freezing rain, ice pellets, or snow), and cold temperatures.

Winter storms occur when warm, humid air meets cold air along a front separating the two air masses. At first the front is slow moving or stationary. A cyclonic storm starts when a deep low-pressure centre forms, and the wind speed increases in the rotating system. Warm, moist air is lifted upward, producing clouds and precipitation along the front.

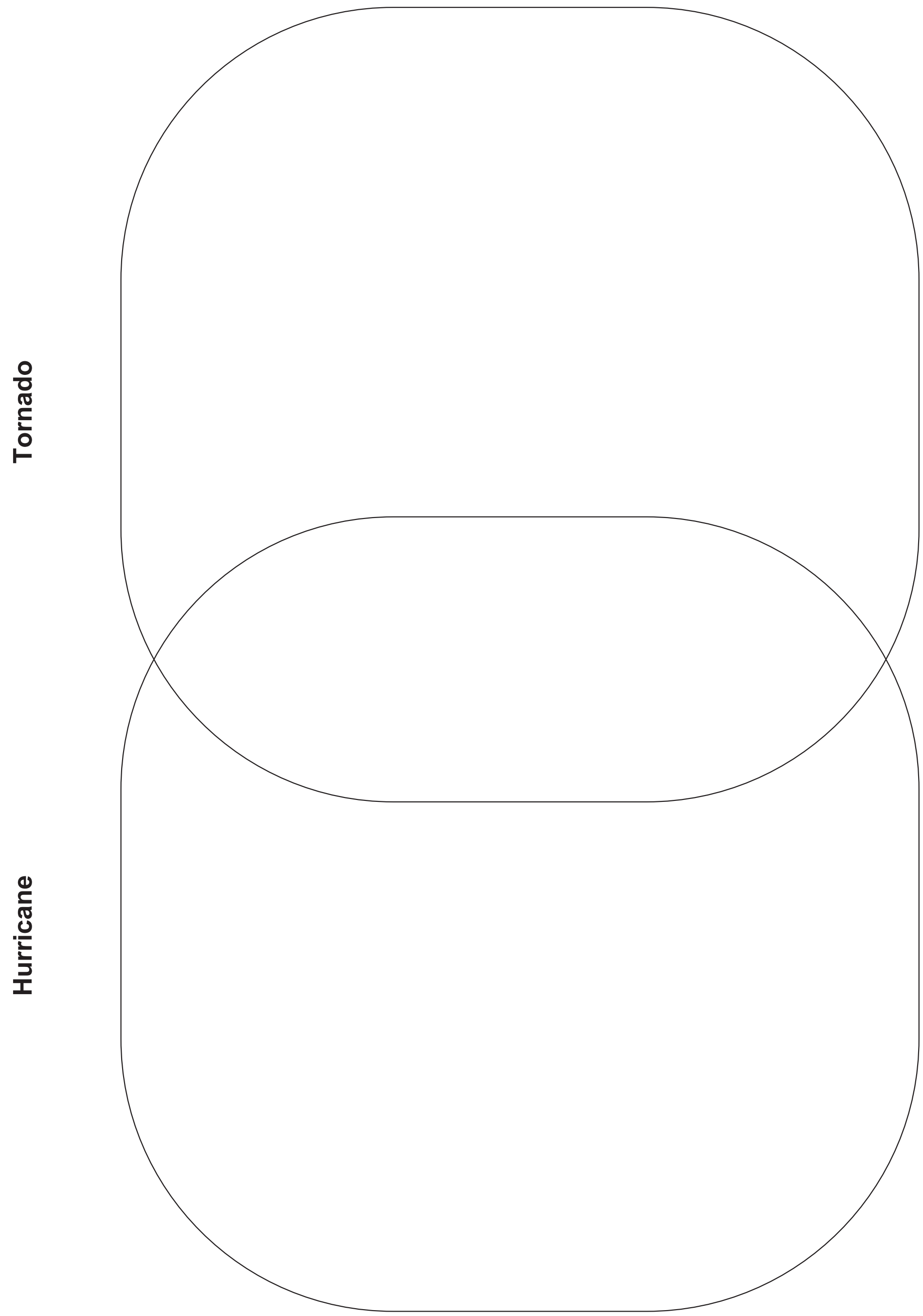
A **blizzard** comes about when winds exceed 50 kilometres per hour with snow and blowing snow that reduce visibility to near zero. The wind chill is usually high during a blizzard.

Learning Activity 4.5: Severe Weather

You will compare and contrast what you've learned about hurricanes and tornadoes using the Venn Diagram provided. In the two outer areas, list information that is unique to tornadoes on one side and information that is unique to hurricanes on the other side. In the overlapping area in the middle, list information about tornadoes and hurricanes that is the same.

continued

Learning Activity 4.5 (continued)



Check the Learning Activity Answer Key found at the end of this module.

Summary

Weather maps outline the area being surveyed, the names of the cities where the reporting stations are located, and symbols that represent the weather data.

A weather station symbol provides information (the atmospheric pressure, wind speed and direction, cloud cover, temperature, current weather conditions, and dew point) of an exact location.

Although complex, both global and local weather systems are based in simple processes of heat transfer. Fronts, wind patterns, and convection cells (pockets of air where convection is occurring) each result from the unequal buildup of heat energy over Earth's surface.

Storms are very powerful forces that can do great damage. In the next lesson you will learn how meteorologists track severe weather systems and warn the public.

Lesson 5: Tracking Severe Weather Systems

Lesson Focus

After completing this lesson, you will be able to

- ❑ understand the types of technologies used by meteorologists
- ❑ explain the severe weather watch/warning system

Key Words

- weather watch
- weather warning
- weather advisory
- satellite
- radar

Introduction

In the last lesson you learned how severe weather systems form. In this lesson you will learn about the technologies used to track severe weather systems as well as the extreme weather alert system used to keep the public informed of severe weather events.

Extreme Weather Alerts

The Meteorological Service of Canada issues three types of extreme weather alerts that are broadcast by radio and television stations to warn the public when severe weather events are happening.

A **weather watch** means that conditions are present for extreme weather to occur in your area. People within a watch area are advised to be on the lookout for dangerous weather. A **weather advisory** means that severe weather is predicted for your area and a **weather warning** means that extreme weather is highly likely to arrive somewhere in your area or may already be happening, so precautions should be taken.

Just how weather alerts come to be issued is the topic of the rest of this lesson.

Weather Radar

Modern meteorology started during World War II. The use of airplanes at that time made possible the development of balloon-borne instruments to take upper air measurements. The number of weather-observing locations around the world increased, as did the use of computers, and rockets for launching satellites. World War II was the reason radar (an acronym for **RA**dio **D**etection **A**nd **R**anging) was developed.

Radar began as a tool to detect aircraft. Today, one of the major uses for modern radars is to study and predict the development of hail and other forms of severe weather.

Precipitation is not the only target that reflects the radar beam. Almost all radars detect strong echoes that are created by stray signal reflections off trees, hills, buildings, and even lakes in the vicinity of the radar site. These are known as **ground clutter** and can fool the meteorologist who is watching the radar if he or she is not careful.

Precipitation rates can be estimated from the strength of the echoes detected by the radar. The Meteorological Service of Canada has developed a national network of radars to warn the public of severe thunderstorms, tornadoes, and hurricanes. Doppler radar, a more recent improvement, sends out a series of rapid microwave pulses and measures the movement of precipitation droplets in the interval between the pulses. This provides vital clues about the nature and strength of the weather system.

To view a radar map of your area, visit Environment Canada's Weatheroffice website at http://weatheroffice.gc.ca/radar/.

Meteorologists use Doppler radar to identify circulations inside thunderstorms, the development of tornadoes, wind flow in large winter storms, and damaging winds from thunderstorms.

Radar is one of science's major tools for observing weather and precipitation in a time frame that makes it possible for the Meteorological Service of Canada to provide detailed information to the public when it is most needed.

Weather Satellites

Our view of the atmosphere is from the ground looking up. Since most of us can see only a few kilometres in any direction, our view is limited. Weather systems can be hundreds or even thousands of kilometres across. Weather maps and radar have expanded our views, but weather satellites give us a completely different perspective on weather. Orbiting satellites are platforms from which the atmosphere and surfaces below can be observed from the outside. There are several different types of satellites, each one having specific features that produce certain images.

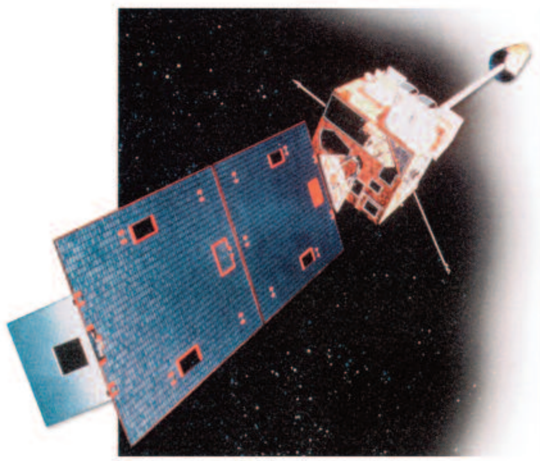


Image credit: © CORBIS. Source: Hirsch, Alan J. *Nelson Science 10: Unit 4*. Scarborough, ON: Nelson Thomson Learning, 2001. Figure 2. 567. Reproduced in accordance with *Access Copyright Elementary and Secondary School Tariff*.

Polar-orbiting satellites scan a strip of Earth, taking less than two hours to complete an orbit. These satellites provide us with information on the condition of the ozone "hole" and composite pictures of snow cover and ocean surface temperatures.

Geostationary weather satellites orbit directly over the equator. There are two geostationary satellites covering Canada and the United States, one for the eastern part and one for the west coast and Pacific Ocean. Each one has a field of view covering about one-third of Earth's surface. Each satellite's view remains the same, so sequential images are viewed in rapid succession to show development and movement of weather systems.

Visible satellite images are views produced from reflected sunlight and look similar to pictures made with an ordinary camera. On visible satellite imagery, clouds appear white, and the ground and water surfaces are dark grey or black. Since this imagery is produced by sunlight, it is only available during daylight hours. Snow cover can be monitored because it does not move as the clouds do. Land features, such as streams, can be visible.

Infrared satellite images are produced by the infrared (heat) energy Earth radiates to space. Since Earth is always giving off heat, infrared images are available day and night.

On infrared images, warm land and water surfaces appear dark grey or black. The cold tops of high clouds are white, and lower-level clouds, being warmer, are grey. Low clouds and fog are difficult to detect in the infrared when their temperatures are nearly the same as nearby Earth surfaces. Infrared images seen on television or computer weathercasts are colour coded (enhanced).

These enhanced images make it possible to keep track of land and ocean surface temperatures. The high, cold clouds associated with severe weather are also easily monitored. Enhanced imagery can be used to estimate rainfall rates. This information is used in flash-flood forecasting.

Weather Features in Satellite Imagery

Hurricanes look like pinwheels of clouds. The beginnings of hurricanes are spotted from satellite views because they occur over large areas of the oceans.

Clouds from which showers fall can look like grains of sand, especially on visible satellite pictures. Thunderstorms appear as “blobs” or “chains of blobs.” They may have neighbouring lower clouds appearing as tiny curved “tails” that are indicators of the possibility of tornadoes.

Meteorologists use satellite images to study cloud shapes, heights, and type. Changes in these cloud properties, along with cloud movement, allow weather forecasters to decide what is happening and what is likely to happen to weather in the hours and days ahead.

Learning Activity 4.6: What Can You See?*

Weather satellites have sensors aboard that detect both visible light and infrared or heat radiation. The sensors providing views of reflected sunlight are engineered to be more detailed than infrared, so that smaller objects can be seen. However, visible images are only available during the day, limiting their continuous monitoring of weather conditions. Although less detailed, infrared views are temperature maps of surfaces viewed from the satellite's vantage point, whether land, water, or clouds. The temperature variations of the surfaces may be enhanced to highlight certain features of interest to meteorologists.

Method

The accompanying drawing shows an Earth surface and atmospheric cross-section. A temperature scale at the left shows the decrease in temperature with an increase in height in the atmosphere. Shade in the temperature-scale blocks with your pencil. Start by making the bottom block darkest, the next one up lighter, the next lighter, and so on. Leave the top block white.

The numbers in the drawing below indicate temperatures of various surfaces. For example, the lake surface is at +23° C, the upper surface of the fog bank is +18° C, and the thunderstorm top is at a very cold –64° C.

The rates of infrared (heat) radiation from objects are related to their surface temperatures. The higher the surface temperature, the greater the radiation. The lower the temperature, the less the radiation. Because of this, the cold tops of high clouds appear white while the tops of warmer low clouds appear grey in infrared pictures (unless the images have been enhanced).

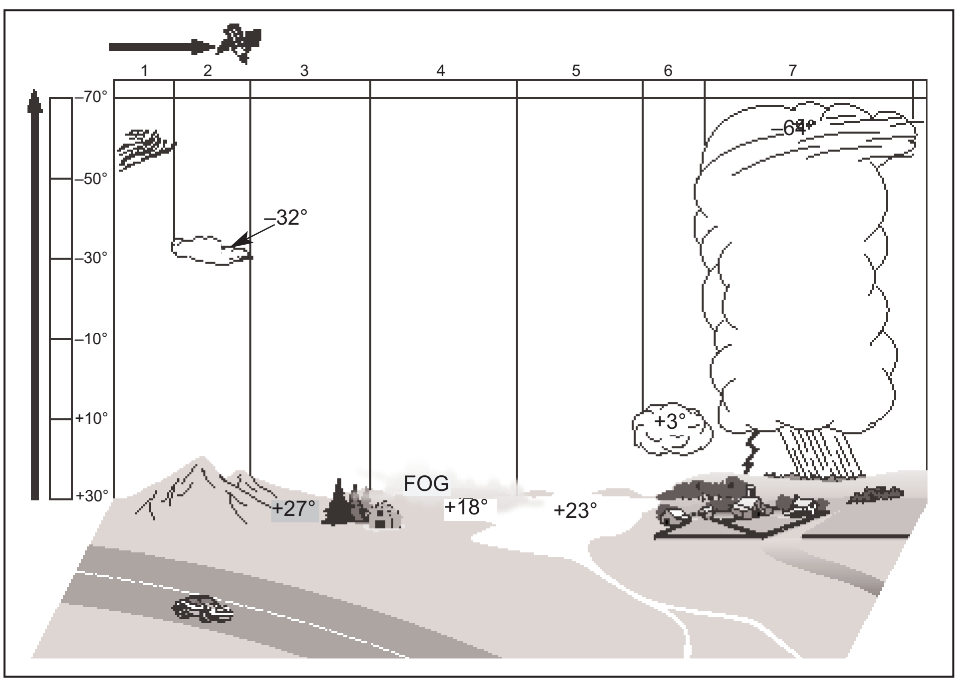
continued

* Source of learning activity, "What Can You See?": Environment Canada. "Module 13: Weather Satellites." *Project Atmosphere Canada*. 2001. www.cmos.ca/ProjectAtmosphere/module13_weather_satellites_e.html (1 May 2012).

Learning Activity 4.6 (continued)

Questions

1. What does a satellite "see" when it senses Earth in reflected sunlight (by visible radiation)? Imagine yourself looking straight down from a satellite moving across the top of the drawing. Your direction of travel is shown by the arrow.
   a. List the sequence of things you would see as you make the trip across the field of view.
   b. Could you see this same scene at night?
2. What does a satellite "see" when it senses Earth by infrared radiation? Imagine yourself making the same scan but now you sense the heat or infrared radiation given off by the upper surfaces of objects.
   a. Select your own shading (or colour enhancement) scale for the temperature at the left of the cross-section. Now, using the shading (or colour enhancement) scale you selected for temperature as a guide, shade (or colour) in the strip at the top of the picture, based on the temperatures of surfaces directly below.



continued

Learning Activity 4.6 (continued)

b. List the sequence of "things" you would see as you scan across the field of view. Could you see as many different things as you saw with visible light? Can you distinguish between land, fog, and water? Were there some things you could "see" better in the infrared scan than in the visible light view? Which are whiter, low or high cloud surfaces?

c. Can you see this temperature scene day or night?

3. In the list below, place a ✓ in the appropriate column to indicate which kind of satellite view (visible or infrared) is better suited to provide the information requested:

	Visible	Infrared
a. 24-hour coverage of atmosphere		
b. finer details of cloud surfaces		
c. temperatures of cloud tops (and, indirectly their heights)		
d. distinguishing fog from surrounding Earth surfaces		
e. determining extent of snow cover on ground		
f. detecting small fair-weather clouds		
g. the colour-coding of cloud tops		

Check the Learning Activity Answer Key found at the end of this module.

Summary

The Meteorological Service of Canada issues three types of extreme weather alerts (watch, advisory, and warning) that are broadcast by radio and television stations to warn the public when severe weather events are happening.

One of the major uses for modern radars is to study and predict the development of hail and other forms of severe weather.

Weather maps and radar have expanded our views, but weather satellites give us a completely different perspective on weather. Orbiting satellites are platforms from which the atmosphere and surfaces below can be observed from the outside.

There are several different types of satellites with each one having specific features that produce certain images.

In the next lesson, you will learn about the costs associated with severe weather systems.

Lesson 6: Social, Environmental, and Economic Impacts of Severe Weather Events

Lesson Focus

After completing this lesson, you will be able to

- ❑ understand the social, economic, and environmental impacts of a severe weather event
- ❑ explain the consequences of personal and societal decision making

Key Word

- EMO (Emergency Measures Organization)

Introduction

In the last lesson you learned how severe weather systems are tracked and about the various alerts used by the Canadian Meteorological Service to warn people of severe weather events. In this lesson you will learn about the aftermath of a severe weather event, Hurricane Katrina, and the impacts such an event has on society, the economy, and the environment.

Hurricane Katrina: A Case Study

The year 2005 saw one of the most destructive hurricanes in history touch down in New Orleans, Louisiana. Hurricane Katrina was the sixth strongest Atlantic hurricane in history. The effects of this hurricane were catastrophic and the people of New Orleans are still rebuilding their lives years after the natural disaster.

Hurricane Katrina: Timeline of Events

Katrina started off as a tropical depression near the Bahamas on August 23, 2005. The next day, the depression strengthened and became a tropical storm. At this point the storm was given the name Katrina. Katrina made a landfall on the coast of Southern Florida as a Category 1 hurricane and caused minimal damage.

After passing over Florida, Katrina weakened and returned to her former status of tropical storm. As Katrina travelled westerly over the Gulf of Mexico, the warm waters allowed the storm to gain intensity. By August 27, the hurricane was a Category 3, and by August 28, it was a Category 4 hurricane that had yet to make landfall. Later in the day on August 28, Katrina was upgraded to Category 5 as it continued to gain intensity. The same afternoon, the storm was large enough to cause damaging winds along the Gulf Coast, even though the eye of the storm was still about 370 kilometres away.

While the hurricane weakened overnight, the storm surge was still high at landfall due to the large waves (over 9 metres in height) Katrina had made while in the Category 4 and 5 phases.

The second landfall of Hurricane Katrina occurred on August 29, 2005, along the coast of Louisiana. Even though the hurricane had just weakened to Category 3 intensity, the winds on the land were still Category 4 strength while the eye of the storm was over the water. Many towns along the coast, as well as the eastern part of New Orleans, were severely damaged by the record storm surge and strong winds in excess of 205 kilometres per hour.

A few hours later, after weakening a bit more, Hurricane Katrina made landfall for a third time, close to the Louisiana-Mississippi border. At this point, the hurricane was still Category 3 with sustained winds of about 195 kilometres per hour.

For facts, photographs, maps, and videos related to Hurricane Katrina, visit the "Hurricane Katrina" page of the *Earthly Issues* website at www.earthlyissues.com/katrina.htm.

The Effects of Hurricane Katrina

Social Impacts

Life on the Gulf Coast was halted for several weeks. For many residents, life never returned to normal at all. Quality of life was severely affected by Hurricane Katrina in many ways, including the following:

- One million people were evacuated from the city of New Orleans, but 20 000 to 25 000 people remained in the city and were transported to the Superdome for emergency shelter.
- Extensive flooding stranded many residents on the rooftops of their homes and in their attics, awaiting rescue.
- Clean water was unavailable. Many people became dehydrated and sick from contaminated water supply.
- Power outages lasted for weeks. This meant that every electrical appliance that makes life more convenient was unable to function.
- Hospitals and hotels reported diesel fuel shortages and were unable to access power from their generators. This affected the care of the sick people in the hospitals.
- The loss of life was significant. (The official death toll is listed as 1836 people).
- Most forms of radio communication were not possible, due to broken lines and base stations. All local television stations were unable to operate. Residents could not receive updates regarding rescue efforts and when they might expect help to arrive or where to go to get supplies.
- Major roads entering and exiting New Orleans were severely damaged and one major bridge collapsed. This made travel in and out of the city difficult, which further stressed evacuation and rescue work.

Environmental Impacts

In the days following Hurricane Katrina, the spills and leaks of oil and toxic chemicals proved to be numerous and widespread. Considering that there were about 350 000 ruined and abandoned vehicles due to flooding, each one having some gas in the tank, this translated to about 11.4 million litres of spilled gasoline. Additional oil spills in the area from flooded holding tanks and refineries added another 26.5 million litres of petroleum, which brought the estimated oil spill to a total of 37.9 million litres. Some of this oil has been cleaned up, but much remains in the environment where it has polluted water, soil, and air. Several areas of New Orleans reported toxic and hazardous vapours in the air resulting from these oil spills. Exposure to these chemicals may have long-term effects such as increases in cancers and asthma.

A second major environmental problem that resulted was the debris. Hurricane Katrina generated enough debris to cover 100 football fields, each one almost 20 metres deep with waste. This is more debris than any other hurricane and even more than was created by the attacks on the World Trade Center on 9/11. What do we mean by *debris*? This is all the waste and garbage created by items such as the following:

- ruined automobiles
- downed trees and vegetation
- destroyed housing
- more than 220 000 damaged appliances
- steel and scrap metal from destroyed buildings and factories
- broken glass

Who will take all this debris away? Where will it go? Some materials can be recycled. However, burning debris like wood will only further add to environmental concerns, since most of these materials are soaked with petroleum and toxic waste. Disposal of this material presents an enormous challenge with no easy answers.

Plants and animals were also negatively affected by the gasoline spills, and many organisms died as a result. The Gulf Coast area is home to sensitive and ecologically important freshwaters and marshes. These areas have been contaminated with storm surge salt water as well as toxic waste and petroleum. Many rare birds, fish, and shrimp are in danger until their ecosystems are cleaned up and returned to a healthy state.

Economic Impacts

Some business has been created by the hurricane. Examples include the following:

- Contracts for over a billion dollars for debris hauling and disposal have been issued.
- Trailer sales have boomed, as temporary shelter is required for residents and workers returning to the area.

However, the following businesses were affected negatively:

- The seafood industry was crippled. Fisherman lost their boats and their gear. Processing plants were flooded and damaged. Even in the coming years, people may be advised against eating fish and shrimp, as they may be affected by pollution in the ecosystem. This was an $81-billion-a-year industry, and the majority of shrimpers and fishermen are now unemployed.

- Insurance companies lost substantial amounts of money as they dealt with millions of claims for personal and business property.
- Many businesses and industries are ruined and non-functional. Even those with the means to rebuild will suffer losses for the years immediately following Hurricane Katrina.
- Tourism suffered, since travellers stopped going to New Orleans.
- The hotel industry requires rebuilding, which directly affects tourism.

Learning Activity 4.7: Hurricane Katrina—A Case Study

Answer the following questions.

1. What actions might have helped the city of New Orleans better prepare for the arrival of Hurricane Katrina?
2. Although more than 80 percent of residents evacuated New Orleans and the surrounding area, an estimated 20 percent remained. What are some possible reasons a person might have stayed knowing that Hurricane Katrina was on the way?
3. Contaminated water was a major problem following Hurricane Katrina. How would a lack of fresh water affect health and daily life following the hurricane? List as many ideas as you can.
4. More than a year after Hurricane Katrina, many people from Louisiana were still living as refugees in other places around the Unites States. Why would rebuilding a life in New Orleans take this long? List as many ideas as you can.
5. Hurricanes are a fact of life on the Gulf Coast. Knowing this, and seeing the devastation caused by Hurricane Katrina, how could people better prepare themselves for the next hurricane?

Check the Learning Activity Answer Key found at the end of this module.

Notes

Assignment 4.2: Research Project (20 marks)

Choose a severe weather event that happened recently in Canada. You can present your research as a written report, a slide show (e.g., PowerPoint) presentation, or an 8½" x 11" poster. Answer the following questions in your presentation.

1. What weather event have you decided to research?
2. What date, time, and place did the event occur?
3. Provide a timeline of the events leading up to this incident.
4. Provide a description of the impact of your weather event. Remember to consider social, economic, and environmental issues.
5. In the aftermath, what was learned, and what could be done differently in the future?

Your assignment will be assessed using the following rubric.

Content	Length and Style	Sources Used	Total
14 marks	3 marks	3 marks	
▪ provides details of the event (name of the event, date, time, location) (*2 marks*) ▪ provides the timeline of event (*3 marks*) ▪ provides social, economic, and environmental impacts (*6 marks*) ▪ provides analysis of aftermath and lessons learned (*3 marks*)	**Report:** At least 1 typewritten page, double-spaced, using a font no larger than 12. **Power point:** At least 5 slides. Text is in a font and colour that is easy to read. Uses backgrounds, transitions, and pictures to enhance the presentation. **Poster:** On 8½" x 11" paper. Clear title and subheadings. Text is organized into sections. Uses colour and pictures to capture attention.	Include a "Works Cited" page at the end of your report that details all of your research resources. **Books:** Include the title, author, and publisher. **Internet Resources:** Include the page name, author, and URL. **Interviews:** Include the name of each person you interview as well as their occupation and place of work.	
			/20

Notes

Lesson 7: Climate Change

Lesson Focus

After completing this lesson, you will be able to

- ❑ explain the difference between weather and climate
- ❑ understand that climate change occurs naturally
- ❑ explain how human activities influences climate change

Key Words

- climate
- ice age
- greenhouse effect
- greenhouse gases
- methane (CH_4)
- carbon dioxide (CO_2)
- water vapour
- emissions
- ice core samples
- fossil fuel
- ice age
- glacier
- chlorofluorocarbons (CFCs)

Introduction

In the last lesson you learned how a severe weather event impacts society, the economy, and the environment. In this lesson you will learn about one of the most debated current issues in science—climate change.

How Are Weather and Climate Related?

Weather is the set of environmental conditions you experience day to day. **Climate** is the set of weather conditions of an area averaged over many years. Weather changes all the time, but climates tend to be more constant.

Warming and cooling trends are part of Earth's normal cycles. Temperatures vary within a given year, from one year to the next, and on longer time scales, over decades, centuries, and millennia. In fact, there have been frequent changes in climate, with repeated swings from colder to warmer conditions. At the peak of the last ice age (about 16 000 years ago), most of Canada was covered with ice.

What Is an Ice Age?

An **ice age** is a period of time when the temperature of Earth is very cold. During an ice age, glaciers cover large amounts of land. A **glacier** is made up of snow and ice that does not melt. As the snow piles up, the weight of the snow on the top presses down on the snow underneath, which then becomes ice. Glaciers get bigger as more snow piles up. They expand as the top layers slide downhill along the bottom layer of ice.

Ice core samples are probably the most important tool that scientists use to study global temperature and when ice ages occurred. Scientists drill deep into the glaciers of Greenland and Antarctica. They pull out ice cores that are about 10 centimetres in diameter and as much as 3 kilometres long. Just like growth rings in trees are made of layers, ice cores are made up of layers of snow.

Each snow layer in an ice core represents one year and provides information about the climate. Fossilized air bubbles trapped in the ice cores help scientists figure out what gases were present in the atmosphere when each layer of snow fell.

In addition to the air bubbles, each thin layer of the ice core can be sampled to see how much airborne dust fell with the snow. Volcanic eruptions leave dust particles in the atmosphere that eventually get "cleaned up" by snowflakes falling. We can figure out how much volcanic activity occurred in the past 500 000 years by finding out what kind of dust, and how much of it, is in each layer.

Climate History

To learn about Earth's climate history, scientists look for clues in plants, on lake bottoms, and on the ocean floor.

Growth rings in trees tell a lot about the climate. In a year with a lot of moisture the rings are wide. During dry years, the rings are thin. Sediment in the bottom of a lake contains pollen and seeds from plants while ocean sediments have fossils of tiny animals. The species of plants and animals that lived in an area give scientists information about temperature and moisture that were present during that time. This allows them to make predictions about how much precipitation fell in the past.

Rising Temperatures

Scientists believe Earth is getting warmer because of an increase in **greenhouse gases** such as **carbon dioxide** (CO_2) in the atmosphere. Since the Industrial Revolution, ice core samples have had higher levels of carbon dioxide. Global temperatures have increased about 0.5°C over the last 100 years. This is 10 times faster than in the past.

In Lesson 2 you learned that about one-third of the incoming radiation from the Sun is reflected back into space by the atmosphere and Earth's surface. The remainder is absorbed by Earth, clouds, and the atmosphere.

Earth's atmosphere does the same thing as a greenhouse. Gases in the atmosphere such as carbon dioxide do what the roof of a greenhouse does. Sunlight shines in and warms the plants and air inside. But the heat is trapped by the glass and can't escape. During the day, the Sun shines through the atmosphere. Earth's surface warms up in the sunlight. At night, Earth's surface cools, releasing the heat back into the air. But some of the heat is trapped by the greenhouse gases in the atmosphere. The so-called "**greenhouse effect**" is caused by gases such as carbon dioxide (CO_2) and **water vapour**. The greenhouse effect is necessary for keeping temperatures within a range that is acceptable for most life on Earth.

Greenhouse Gases

Greenhouse gas is the name scientists give to natural or polluting gases that have an impact on the heat-trapping properties of the atmosphere.

The main greenhouse gases are water vapour, carbon dioxide (CO_2), **methane (CH_4)**, and **chlorofluorocarbons** or **CFCs** (found in solvents, refrigerator coolants, and aerosol propellants).

Industrial and household **fossil-fuel** (gas, oil, and coal) consumption, as well as natural and accidental forest fires, are the main sources of carbon dioxide, whereas methane is a by-product of agriculture (crops and livestock). Many governments around the world are worried about the consequences of an increase in the greenhouse effect.

The Great CO_2 Buildup

Global CO_2 concentrations in the atmosphere have increased 30 percent since the start of the Industrial Revolution in the 1700s. The cause of the rapid buildup of CO_2 is human activities: burning fossil fuels (coal, oil, and natural gas), agricultural practices, and deforestation. Scientists predict that atmospheric CO_2 concentrations will double from pre-industrial levels in the next 40 to 60 years.

The Global Carbon Balance

Carbon occurs in the atmosphere and oceans mainly in the form of CO_2 (carbon dioxide gas) and as dissolved carbonates (found in rocks). Huge amounts of carbon are also stored within Earth in fossil fuels and sedimentary rocks such as limestones, and on Earth's surface in vegetation and soils. Before the Industrial Revolution, atmospheric concentrations of CO_2 and other greenhouse gases did not change much because any addition was balanced by removal.

How Do We Measure Up in Canada?

Canada's Carbon Dioxide Emissions

In 2005, Canadians contributed about 747 megatons of carbon dioxide to the atmosphere. Canada has about 0.5 percent of the world's population but produces 2 percent of global CO_2 emissions. On a per-person basis, this puts us in second place among the world's leading emitters of carbon dioxide (just behind the United States), with each Canadian taking the responsibility for about 23 tonnes of the total.

How Can You Help?

To help reduce greenhouse gas **emissions**, you can do the following:

- Turn off light appliances, televisions, and computers when they're not needed.
- Walk or bike for short trips.
- Take the bus or carpool.
- Use energy-efficient lighting, appliances, building products, and vehicles.

Learning Activity 4.8: Greenhouse Gases

1. Identify human activities that have an influence on greenhouse gases.
2. Identify natural activities that have an influence on greenhouse gases.
3. Complete the Concept Overview for the phrase *greenhouse gases*.

continued

Learning Activity 4.8 (continued)

Concept Overview

Key word or concept

greenhouse gases

Write an explanation or definition in your own words. You will be paraphrasing.

Draw a figurative representation.

List facts (at least five).

Create your own questions about the concept.

Create an analogy.

Concept Overview Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Check the Learning Activity Answer Key found at the end of this module.

Summary

Weather is the set of environmental conditions you experience day to day. Climate is the set of weather conditions of an area averaged over many years. Warming and cooling trends are part of Earth's normal cycles.

Ice core samples are an important tool that scientists use to study global temperature. To learn about Earth's climate history, scientists look for clues in plants, on lake bottoms, and on the ocean floor.

Scientists believe Earth is getting warmer because of an increase in greenhouse gases such as carbon dioxide (CO_2) in the atmosphere. Since the Industrial Revolution, ice core samples have had higher levels of carbon dioxide. Global temperatures have increased about 0.5°C over the last 100 years.

The main greenhouse gases are water vapour, carbon dioxide (CO_2), methane (CH_4), and chlorofluorocarbons or CFCs (found in solvents, refrigerator coolants, and aerosol propellants).

In the next and last lesson of Weather Dynamics, you will learn about the consequences of climate change and the effects of global warming.

Notes

Lesson 8: Consequences of Climate Change

Lesson Focus

After completing this lesson, you will be able to

- ❑ understand the social, economic, and environmental impacts of climate change
- ❑ explain the consequences of personal and societal decision-making

Key Words

- global warming
- El Niño (warmer ocean currents)
- La Niña (cooler ocean currents)

Introduction

In the last lesson you learned what climate change means and how climate change is brought about through natural processes and human activities. In this lesson, you will be introduced to potential consequences of climate change and how these consequences will affect society, the economy, and our environment.

Learning Activity 4.9: Positives and Negatives of Climate Change

As you read through this lesson, keep track of the positives, negatives, and interesting characteristics/implications of climate change.

Climate Change

Positive Characteristics	Negative Characteristics	Interesting Characteristics and Implications

Check the Learning Activity Answer Key found at the end of this module.

What Types of Changes Can We Expect?

We see signs of climate change throughout the northern region of our province: average annual temperatures are increasing; severe rainstorms have become more frequent; winters are getting shorter; permafrost is melting; freeze-up is later and thawing of ice roads is earlier; and sea and lake ice cover is not lasting as long.

- **Temperature**: Most climate change projections for the Prairies show an increase in temperature under a global warming scenario. Extreme heat events will be more common. Growing seasons could be longer, and summer recreational seasons and winters could be shorter.
- **Precipitation**: The frequency of heavy rainstorm events is expected to increase in some areas, while severe droughts and drier soils can be expected in other areas. During dry summers, higher temperatures under warmer climates will create increased evaporation and drought conditions. There may also be wetter periods when air temperatures are cooler. Soil moisture conditions could become unpredictable. With less precipitation in winter, there may be decreased need for snow removal and reduced winter-heating costs, but increased demand for air conditioning in summer.
- **Ice cover**: Declines in ice cover in the northern part of our province have been recorded, with the largest impact on ice roads (shortened season for transportation) and ice flows affecting the polar bear population's ability to hunt in the Arctic.
- Projected changes in rainfall, evaporation, and groundwater recharge rates (renewing water levels underground) will affect all freshwater users.
- Flood-absorbing capacities of wetlands and floodplains will be affected, and increased erosion, flooding, and runoff (water from agricultural lands) polluted with nutrients and pesticides can be expected.
- Changes in growing seasons, acidity of soils, and moisture content, and severe weather events such as hail, thunderstorms, and tornadoes will have an impact on agriculture in the province.
- Increased risk of pests and pathogens entering our province due to warmer temperatures will affect forestry, agriculture, animals, and humans. Some diseases carried by insects, such as Lyme disease (carried by ticks) and West Nile encephalitis (carried by mosquitoes), as well as water-borne infectious diseases, such as cryptosporidiosis or giardiasis, may become more frequent.
- Increased heat stress, smog, and ground-level ozone may increase asthma and other respiratory diseases.

- A loss of native plant and animal species may occur as they may not be able to adapt to changing temperatures. An increase of invasive species that are better adapted to changed conditions may enter our ecosystem.
- Changes in lakes' temperatures may result in oxygen depletion affecting fish stocks and the commercial fishing industry. Tourism may also be affected as recreational fishing, skiing, snowmobiling, ice fishing, and swimming could be negatively affected.
- Warmer temperatures will likely cause the boreal forest to shrink and other forest species to move northward. Twenty-five percent of Manitoba's economy is based in the forest industry. Agriculture may someday be expanded into northern areas where currently the growing season is too short.
- Costs would increase in the way of taxes and insurance due to weather-related disasters such as droughts, blizzards, floods, heat waves, hailstorms, snowstorms, thunderstorms, forest fires, and tornadoes.
- The environment and global economy are affected by the ocean and atmospheric system of the tropical Pacific. **El Niño** (pronounced Neen-yo, meaning "the little boy" in Spanish) is the name given to the periodic warming of the Pacific Ocean current along the coasts of Peru and Ecuador. **La Niña** (Neen-yah, which translates as "the little girl") is the periodic cooling of the eastern Pacific Ocean. Both of these conditions affect weather patterns around the world. Some of the larger impacts of El Niño and La Niña experienced by developing countries in the tropics include drought, especially when accompanied by high temperatures, which causes crops to wither and die, reduces the public water supply, and increases the likelihood of wildfire.

  In other areas, exceptionally heavy rains trigger flash flooding that drowns crops, washes away motor vehicles, destroys houses and other buildings, and disrupts public utilities.
- In Canada, El Niño winters tend to be mild and less wet than normal. The exceptions are in the Atlantic provinces and the territory of Nunavut in the Canadian Arctic, which are usually milder but wetter than normal. La Niña, on the other hand, usually results in colder temperatures in Canada in winter. La Niña winters are usually also wetter than normal in western Canada, southern Ontario and Quebec, and the Atlantic provinces, while being drier than normal elsewhere.
- Climate change is expected to bring change in the size of extreme flows in Prairie rivers. This could cause large flows to increase in size, but it could also cause low flows to decrease. The impacts for a given river will depend on the location and the source of water for the river.

How Can We Adapt?

Improving building design and reducing transportation needs will help decrease energy demands. Increasing public/mass transit and encouraging use of hybrid and other low-emission vehicles can help reduce our transportation emissions, as well as improve air quality. Water conservation practices can help reduce the amount of water we use in our homes, schools, and at work. Planting drought-tolerant plants in yards and parks, and landscaping areas to maximize water storage, are good ways to reduce the need for water in summer.

Using improved agricultural techniques, like reduced tilling of the soil, can greatly reduce the loss of top soil due to wind erosion. Changing agricultural practices by using conservation farming that improves soil conservation and soil moisture or adapting by irrigating crops and converting to drought-tolerant crops provides other options of improving yields in a drier climate.

Summary

Climate change is creating a demand for good ideas that will reduce our greenhouse gas emissions: new technologies, alternative energy sources, progressive government policies, and lifestyle choices. We can be innovators at home, at work, in the marketplace, and within our communities.

Notes

Assignment 4.3 Climate Change Discussion (20 marks)

1. Explain how an increase in greenhouse gases may affect extreme weather events. (*2 marks*)

2. Suggest reasons why there are more concerns about global warming today than in the past. (*3 marks*)

3. Refer to the positive/negative/implications chart you filled out in Learning Activity 4.9, and discuss the impact of climate change on northern communities in our province. Remember to consider the potential economic, social, and environmental consequences of both the warming and cooling of Manitoba's climate. (*6 marks*)

continued

Assignment 4.3 (continued)

4. In 1995 Canada's CO_2 emissions were 500 megatons. In 2005 our CO_2 emission rose to 747 megatons while countries like Germany and Japan had decreases in their emissions. If you were a government official, what stand would you take on this issue? Explain what course of action you would take and how you would go about accomplishing your goal. (*3 marks*)

5. Reflect upon all you have studied in this module, and develop a list of life practices that promote sustainability. Be sure to include practices related to health and well-being, the economy, and the environment. (*6 marks*)

This completes your work in Grade 10 Science. If you have not yet made arrangements to write your **final examination**, then do so now. The instructions are provided in the course Introduction.

Completing Your Practice Final Examination

Getting the Most Out of Your Practice Final Examination

Like the final examination that you will be writing, your Practice Final Examination is based on Modules 3 and 4. It is very similar to the actual Final Examination. This means that if you do well on your practice examination, you should do well on the final examination because you will have learned the content. You will also feel more confident and less nervous about writing the examination.

The Practice Final Examination and answer key can be found in the learning management system (LMS). Complete the Practice Final Examination and then check your answers against the key.

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 Final Examination and its answer key.

To get the most out of your Practice Final Examination, follow these steps:

1. Study for the Practice Final Examination as if it were an actual examination.
2. Review those learning activities and assignments from Modules 3 and 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 3 and 4, including all of your notes, learning activities, and assignments.
5. Bring the following to the Practice Final Examination: pens and pencils (two or three of each), blank paper, and a metric ruler. You may also bring a calculator.
6. Write your Practice Final 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.

Submitting Your Assignments

It is now time for you to submit Assignments 4.1 to 4.3 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.

- ❑ Assignment 4.1: Energy Flow
- ❑ Assignment 4.2: Research Project
- ❑ Assignment 4.3: Climate Change Discussion

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

Module 4

Learning Activity Answer Key

MODULE 4
LEARNING ACTIVITY ANSWER KEY

LESSON 1

Learning Activity 4.1: Comparing and Contrasting the Atmosphere and Hydrosphere

1. Complete the following Compare and Contrast frame for the terms *atmosphere* and *hydrosphere*.

Compare and Contrast

C
O
M
P
A
R
E

How are atmosphere and hydrosphere alike?

- **contain water vapour**
- **made up of different layers or parts**
- **sustain life**
- **some component parts are in very small concentrations**
- **weather happens as a result of interaction between the two**

C
O
N
T
R
A
S
T

How are *atmosphere* and *hydrosphere* different?

Atmosphere	Hydrosphere
• **contains gases** • **above Earth** • **protects against UV rays**	• **contains all forms of water** • **on and in Earth (except water vapour)** • **moderates climate (heat capacity)**

Write a statement to compare and contrast the two terms, concepts, or events.

While the atmosphere contains gases and surrounds our planet, the hydrosphere contains water and covers 97% of our planet's surface. Both are essential for sustaining and protecting life on Earth and the interaction of both results in the weather and, ultimately, the climate we experience.

Compare and Contrast Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Learning Activity 4.2: Colour Coding Earth's Surface

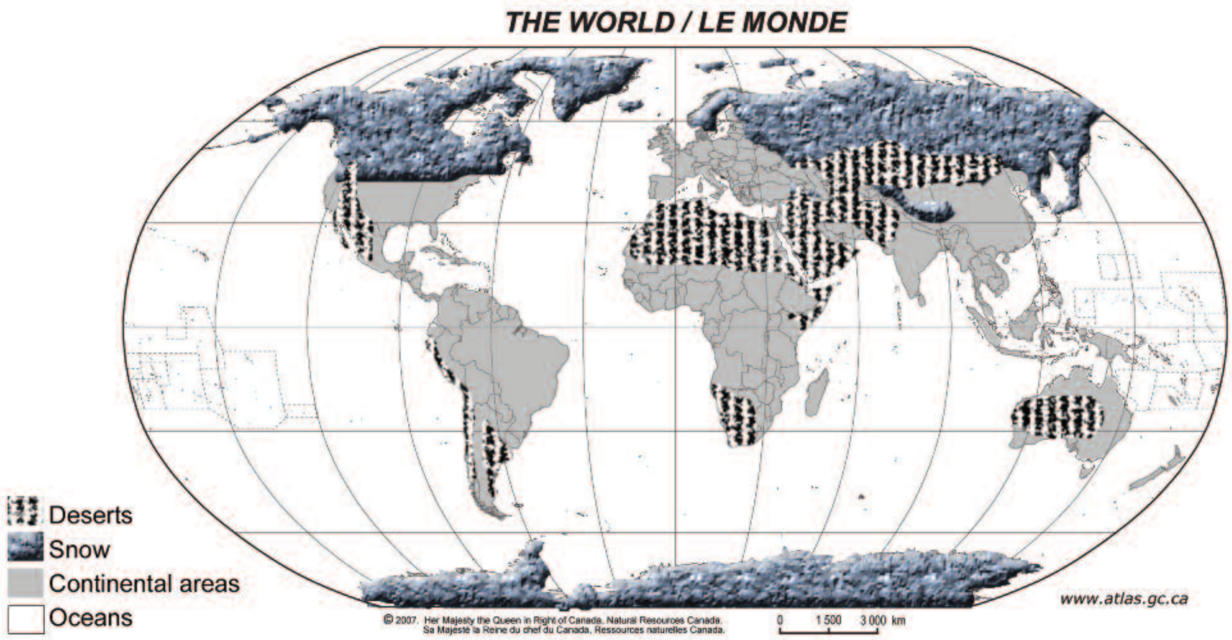
The following graphic shows Earth's surface (oceans and continents), including areas that are snow-covered in winter and major desert areas. Fill in the oceans in red (since they retain most of the incoming solar energy), the snow-covered areas in light blue (since they simply reflect most of the Sun's rays), the deserts in light brown, and the other continental areas in green.

How different does Earth look now?

The smallest amount of area is coloured light brown, next is light blue, then green, and the largest amount of area is coloured red.

Identify the areas that have a high albedo (high reflectance) and a low albedo (low reflectance).

Snow-covered areas and light-coloured areas like sand (deserts) have a high albedo. Continents have a low albedo. Water reflects light and has a higher albedo than land, even though water has a high heat capacity.



Source: Natural Resources Canada. "The World." *The Atlas of Canada*. 7 May 2007. http://atlas.nrcan.gc.ca/site/english/maps/reference/outlineworld/world01 (20 Apr. 2012). Adapted with permission of Natural Resources Canada 2012, courtesy of the Atlas of Canada.

Learning Activity 4.3: It's Because Earth Turns

Investigations

Where options are contained in [brackets], CIRCLE the response that you believe is the correct one.

1. Orient B in the "cross" position as shown in the drawing. If positioned properly, a straight arrow should point towards the ★. Place your pencil point at the centre of the Start Position X. Carefully draw a line on B along the cut-edge and directly towards the ★. The line you drew represents a path that is **[(straight) (curved)]**.
2. Now investigate how rotation affects the path of your pencil lines. Again begin with B in the "cross" position with the direction arrow pointing towards the ★. Pulling the lower left tab towards you, rotate B counter-clockwise through one division of the curved scale (on B). Make a pencil dot on B along the straight scale at one scale division above the Start Position X. Continue rotating B counter-clockwise one division at a time along the curved scale, stopping each time to mark a pencil dot on B at each successive division along the straight scale. Repeat these steps until you reach the curved scale. Starting at X, connect the dots with a smooth curve. Place an arrowhead at the end of the line to show the direction of the motion. The line you drew on B is **[(straight) (curved)]**.

3. You actually moved the pencil point along a path that was both straight and curved at the same time! This is possible because motion is measured relative to a frame of reference. (Familiar frames of reference are east-west, north-south, up-down.) In this activity, you were using two different frames of reference, one fixed and the other rotating. When the pencil-point motion was observed relative to the fixed A and ★, its path was **[(straight) (curved)]**. When the pencil motion was measured relative to B, which was rotating, the path was **[(straight) (curved)]**.

4. Begin again with B in the "cross" position and the arrow pointing towards the ★. Pulling the lower right tab towards you, rotate B clockwise one division of the curved scale and make a pencil dot on B along the straight scale at one scale division above the Start Position X. Continue in similar fashion as you did in Item 2 to determine the path of the moving pencil point. The path was straight when the pencil-point motion was observed relative to **[(A) (B)]**. The path was curved when the pencil motion was measured relative to **[(A) (B)]**.

5. Imagine yourself shrunk down in size, located at X, and looking towards the ★. You observe all three situations described above (that is, no motion of B, counter-clockwise rotation, and clockwise rotation). From your perspective at the X starting position, in all three cases the pencil point moved towards the ★ along a **[(straight) (curved)]** path.

6. Watching the same motion on B, the pencil path was straight in the absence of any rotation. However, the pencil path curved to the **[(right) (left)]** when B rotated counter-clockwise. When the rotation was clockwise, the pencil path curved to the **[(right) (left)]**. This apparent deflection of motion from a straight line in a rotating coordinate system is called the Coriolis effect for Gaspard Gustave de Coriolis (1792–1843) who first explained it mathematically. Because Earth rotates, objects moving freely across its surface, except at the equator, exhibit curved paths.

7. Imagine yourself far above the North Pole, looking down on Earth below. Think of B in the AMS Rotator as representing Earth. As seen against the background stars, Earth rotates in a counter-clockwise direction. From your perspective, an object moving freely across Earth's surface would move along a **[(straight) (curved)]** path relative to the background stars (depicted by the ★ on the AMS Rotator). Now think of yourself on Earth's surface at the North Pole at the dot position while watching the same motion. From this perspective, you observe the object's motion relative to Earth's surface. You see the object moving along a path that **[(is straight) (curves to the right) (curves to the left)]**.

8. Imagine yourself located far above the South Pole. As seen against the background stars, Earth rotates in a clockwise direction. The sense of rotation is reversed from that at the North Pole because you are now looking at Earth from the opposite direction. An object moving freely across Earth's surface is observed to move along a **[(straight) (curved)]** path relative to the background stars. Now think of yourself on Earth's surface at the South Pole while watching the same motion. From this perspective, you observe the object's motion relative to Earth's surface. You see the object moving along a path that **[(is straight) (curves to the right) (curves to the left)]**.

9. In summary, the Coriolis effect causes objects freely moving horizontally over Earth's surface to curve to the **[(right) (left)]** in the Northern Hemisphere and to curve to the **[(right) (left)]** in the Southern Hemisphere.

Learning Activity 4.4: Reading a Weather Map

1. Over what area do you find a cold front?

   There is a cold front over Florida and Georgia.

2. What type of front is over the northeastern United States?

   There is a stationary front over the northeastern United States.

3. Locate the areas of high pressure. What do you notice about the isobars around the high pressure areas?

   The numbers on the concentric circles get smaller as you move away from the centre.

4. Locate the weather glyph near Edmonton.

   a. What is the temperature?

      –6°F (This is a National Weather Map not Canadian, so temperatures will be in Fahrenheit not Celsius.)

   b. What is the dew point?

      –13°F

   c. What is the cloud cover?

      Complete overcast (shading in the circle)

   d. What is the atmospheric pressure?

      295 atmospheres

   e. In what direction is the wind blowing?

      The wind is blowing from the north.

5. Symbols for sky cover have also been included on this chart.
    a. In general, do you find cloudy or clear skies in low-pressure areas?
       You find cloudy skies in low-pressure areas.
    b. In high-pressure areas, what occurs with cloud cover?
       You find clear skies in high-pressure areas.
6. Using the symbols on this map, identify what the weather is like in Churchill (include percentage of cloud cover, temperature, and wind direction).
   In Churchill, there will be clear skies, a temperature of –30°F, and wind from the northwest.

Learning Activity 4.5: Severe Weather

Hurricane

- large system—covering hundreds of kilometres
- looks like a flat, round disc of rotating clouds
- brings rains, strong winds, and flooding
- starts in low-pressure area over water with moist, warm air rising
- spirals due to Coriolis effect
- has eye where there is no rain or wind
- winds create storm surges
- lasts over a week
- weakens when it reaches land

Both

- both have high winds and cause severe damage
- both can cause death and property damage
- both are associated with low-pressure areas
- both have spiral swirling clouds

Tornado

- small system—few to many metres across
- looks like a funnel
- starts over land
- brings loud systems with lightning
- made of high wind speeds
- occurs when a cold front moves into an area with hot humid air
- air pressure inside is extremely low
- veers on an unpredictable path
- lasts only a minute or two

Learning Activity 4.6: What Can You See?

Questions

1. What does a satellite "see" when it senses Earth in reflected sunlight (by visible radiation)? Imagine yourself looking straight down from a satellite moving across the top of the drawing. Your direction of travel is shown by the arrow.

   a. List the sequence of things you would see as you make the trip across the field of view.

      As the visible image satellite passes over this scene, the satellite sees the following in the sequence of blocks 1 to 7:

      Block 1: bright white of the clouds

      Block 2: very light grey of the reflected light from the small cloud

      Block 3: very dark grey (low albedo) from the warm ground

      Block 4: dark grey from light reflected back from the wet fog

      Block 5: dark signal from the warm, reflective surface of the lake

      Block 6: light grey from the warm (3°C), low clouds

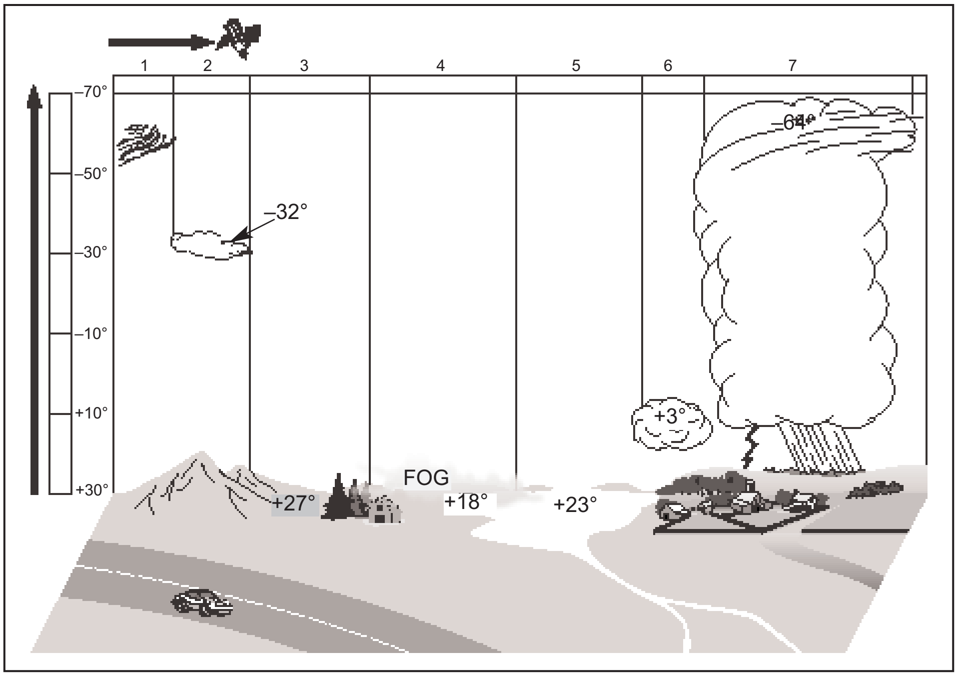
      Block 7: bright white from the very reflective tops of the cold thunder clouds (–64°C)

   b. Could you see this same scene at night?

      No, visible satellite images only work during the day.

2. What does a satellite "see" when it senses Earth by infrared radiation? Imagine yourself making the same scan but now you sense the heat or infrared radiation given off by the upper surfaces of objects.

   a. Select your own shading (or colour enhancement) scale for the temperature at the left of the cross-section. Now, using the shading (or colour enhancement) scale you selected for temperature as a guide, shade (or colour) in the strip at the top of the picture, based on the temperatures of surfaces directly below.



b. List the sequence of "things" you would see as you scan across the field of view. Could you see as many different things as you saw with visible light? Can you distinguish between land, fog, and water? Were there some things you could "see" better in the infrared scan than in the visible light view? Which are whiter, low or high cloud surfaces?

Block 1: orange to red colour of the very cold clouds

Block 2: very light orange of the heat transmitted from the small cloud

Block 3: very dark green (low albedo) from the warm ground

Block 4: green from light reflected back from the wet fog

Block 5: dark green from the warm, heat-retaining surface of the lake

Block 6: light grey from the warm (3°C) low clouds

Block 7: strong red from the very reflective tops of the cold thunder clouds (–64°C)

c. Can you see this temperature scene day or night?

Yes, you could as "heat" is transmitted all the time.

3. In the following list, place a ✓ in the appropriate column to indicate which kind of satellite view (visible or infrared) is better suited to provide the information requested:

	Visible	Infrared
a. 24-hour coverage of atmosphere		✓
b. finer details of cloud surfaces	✓	
c. temperatures of cloud tops (and, indirectly their heights)		✓
d. distinguishing fog from surrounding Earth surfaces		✓
e. determining extent of snow cover on ground	✓	
f. detecting small fair-weather clouds	✓	
g. the colour-coding of cloud tops		✓

Learning Activity 4.7: Hurricane Katrina—A Case Study

Answer the following questions.

1. What actions might have helped the city of New Orleans better prepare for the arrival of Hurricane Katrina?

   The following actions might have helped New Orleans better prepare:

   - **having the supplies on hand to ensure survival after the hurricane, like water and preserved food**
   - **planning earlier evacuation orders**
   - **supplying earlier and more frequent weather bulletins—these weather bulletins need to be issued via several means of communication so that as many residents as possible get the news**
   - **designing levees and flood walls more effectively**
   - **organizing emergency help from other states to come sooner**

2. Although more than 80 percent of residents evacuated New Orleans and the surrounding area, an estimated 20 percent remained. What are some possible reasons a person might have stayed knowing that Hurricane Katrina was on the way?

   - **People may have felt that they were sufficiently protected by their home or building (no real need to leave).**

- **There may have been a lack of financial resources to leave (e.g., money for bus fare) or access to transportation to leave the area (e.g., place to get a bus).**
- **People may have had a feeling of obligation to stay and protect their property.**
- **The stress of evacuation may have been more of a hazard to some people than the danger of dealing with the hurricane.**
- **People may have been unwilling to leave their pets and belongings behind.**

3. Contaminated water was a major problem following Hurricane Katrina. How would a lack of fresh water affect health and daily life following the hurricane? List as many ideas as you can.

   A lack of fresh water would have the following possible effects:

   - **no drinking water, which would lead to an increased danger of dehydration**
   - **no clean water for cooking, washing dishes, or bathing**
   - **no water to flush toilets, which would lead to unsanitary conditions**
   - **corpses (dead bodies) were decomposing in the water, which increased contamination of standing water**
   - **sewer backup would lead to waste floating in the flood water and increased levels of toxic bacteria**
   - **food poisoning from contaminated water used in cooking and washing**
   - **increased spread of illnesses like cholera, typhoid fever, hepatitis A, and tuberculosis from use of contaminated water supply**
   - **petroleum products (e.g., gasoline) in the water posing long-term health risks for all life forms in the area**

4. More than a year after Hurricane Katrina, many people from Louisiana were still living as refugees in other places around the Unites States. Why would rebuilding a life in New Orleans take this long? List as many ideas as you can.

   - **Insurance companies are backlogged with claims, so people are waiting long periods to get money to rebuild their homes and businesses.**
   - **Housing was destroyed in many areas and personal property is gone so people have nothing to go back to.**
   - **People may no longer have employment in the area if their company or employer has not yet rebuilt.**

- **People may have no money to get back to Louisiana if they have not been working.**
- **Destruction was so massive and widespread that it will take several years for life to return to normal in the area.**

5. Hurricanes are a fact of life on the Gulf Coast. Knowing this, and seeing the devastation caused by Hurricane Katrina, how could people better prepare themselves for the next hurricane?
   - **People could stock emergency supplies, like water, batteries, and preserved food. This emergency supply should be enough to last two weeks or more, in case help takes that long to arrive again.**
   - **Evacuation plans should be outlined and communicated to all residents (where to go, when to leave, etc.).**
   - **Levees and flood walls need to be rebuilt to withstand stronger winds and storm surges.**
   - **Detailed disaster preparedness plans involving help from other states should be organized.**

Learning Activity 4.8: Greenhouse Gases

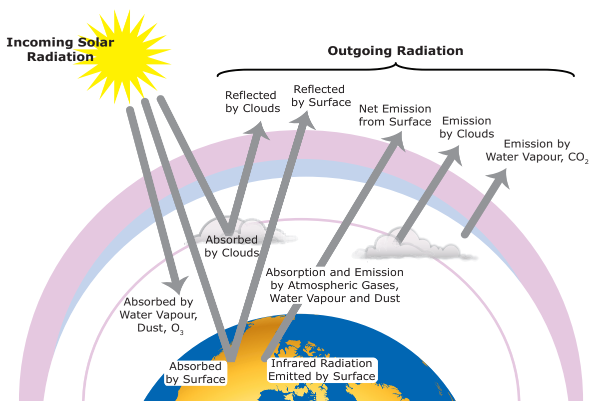
1. Identify human activities that have an influence on greenhouse gases.
   - **use of fossil fuels**
   - **driving vehicles rather than carpooling, using public transit, walking, or biking**
   - **use of inefficient vehicles, appliances, homes—wasting energy**
   - **deforestation**
   - **use of chemicals in the environment like CFCs for refrigeration and in aerosols**
   - **draining wetlands for agriculture**
   - **poor agricultural practices (burning stubble, questionable use of chemicals, intensive livestock operations, which produce methane)**
   - **not conserving or managing water use properly**
2. Identify natural activities that have an influence on greenhouse gases.
   - **forest fires from lightning strikes**
   - **volcanic eruptions**
   - **melting of permafrost from natural cycles of freezing and thawing, which releases stored CO_2**
3. Complete the Concept Overview for the phrase *greenhouse gases*.

Concept Overview

Key word or concept

greenhouse gases

Draw a figurative representation.



Create your own questions about the concept.

Why are car manufacturers still producing cars that use fossil fuels instead of electric batteries? Why aren't incentives offered to encourage the use of solar panels?

Write an explanation or definition in your own words. You will be paraphrasing.

Greenhouse gases are a group of different gases that for the most part naturally occur in our atmosphere. The problem that we now have is that human activities have increased their concentrations and they are absorbing the Sun's energy and trapping it.

List facts (at least five).

- **Scientists believe Earth is getting warmer because of an increase in GHG, such as CO_2 in the atmosphere.**
- **Since the Industrial Revolution, ice core samples have had higher levels of CO_2.**
- **Global temperatures have increased about 0.5ºC over the last 100 years.**
- **The main greenhouse gases are water vapour, CO_2, CH_4, and CFCs.**
- **In 2005, Canadians contributed about 747 megatons of CO_2.**

Create an analogy.

Greenhouse gases trap the Sun's energy like being inside a car with the windows rolled up on a hot sunny day.

Concept Overview Frame: Used by permission of Lynda Matchullis and Bette Mueller. Nellie McClung Collegiate, Pembina Valley S.D. No. 27, Manitoba.

Learning Activity 4.9: Positives and Negatives of Climate Change

As you read through this lesson, keep track of the positives, negatives, and interesting characteristics/implications of climate change.

Climate Change

Positive Characteristics	Negative Characteristics	Interesting Characteristics and Implications
■ **warmer winters** ■ **less snow removal so less fossil fuels used in snow clearing equipment** ■ **fewer accidents with less snow** ■ **not as much energy used to heat homes** ■ **people may go for walks more often if weather is milder, leading to healthier lifestyles** ■ **longer growing seasons**	■ **unpredictable precipitation, so hard to grow crops, which may lead to shortage of food supplies or increased prices** ■ **damage to fragile top soil** ■ **increased evaporation drying up wetlands, ponds, rivers, and lakes, leading to an increased risk of flooding as water does not get stopped if wetland is dried out** ■ **increased heat stress, leading to increased use of air conditioners and fossil fuel to run them** ■ **Decreased ice affecting polar bears' ability to hunt may result in extinction. Also, ice is a source of drinking water in the North, so drinking water shortages may result.** ■ **increased risk of pests, disease, and invasive species** ■ **Fishing and forestry industries affected.** ■ **Tourism also affected.** ■ **increased cost of insurance and health care**	■ **development of new technology as a result of climate change** ■ **new jobs in many areas, for example, developing drought-resistant crops, designing energy-efficient homes, cars, and appliances** ■ **rethinking our use of resources** ■ **rethinking our lifestyles and making changes**

Grade 10 Science (20F)

Practice Final Examination

Grade 10 Science

Practice Final Examination

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 2.5 hours to write this exam.
- Supplies required: pencil or pen, eraser, paper, ruler—you are permitted to bring a calculator, but it is not required
- This exam covers course material from Modules 3 and 4.
- This exam is worth 20 percent of your final mark.

Part A: In Motion

Section 1: Multiple Choice

Choose the best answer. Each question is worth one mark. This section of the final exam is worth 25 marks.

1. Jackson travels 2 km north, then 3 km east, and finally 2 km south. Which statement is true?
   a. Jackson's displacement is 2 km west from his origin.
   b. Jackson is now 3 km east from where he started.
   c. Jackson's displacement is 7 km.
   d. None of the above.

DPSU-03-2014

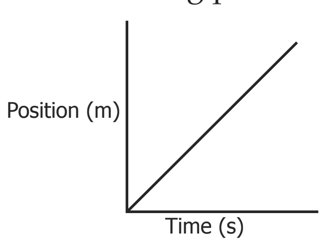
2. Velocity is a measure of
    a. change in position during a change in time
    b. the slope of a position-time graph
    c. displacement during an interval of time
    d. all of the above

3. Which of the following is a vector quantity?
    a. time
    b. velocity
    c. speed
    d. distance

4. A car at accelerates from 0 m/s to 25 m/s in 5 seconds. What is the average acceleration of the car?
    a. 30 m/s^2
    b. 50 m/s^2
    c. 125 m/s^2
    d. 5 m/s^2

5. Which scenario represents an instant of time?
    a. A long-distance runner crosses the finish line at 1 hour, 37 minutes.
    b. A businesswoman takes a two-hour flight from Winnipeg to Montreal.
    c. An ambulance drives for two minutes to arrive at the scene of an accident.
    d. A student leaves home at 8:15 and gets to school at 8:30.

6. What does the following position-time graph tell us about the motion of the object?



    a. The object is accelerating in the positive direction.
    b. The object is moving in the positive direction at a constant velocity.
    c. The object is in uniform motion and headed in the negative direction.
    d. The object is not moving.

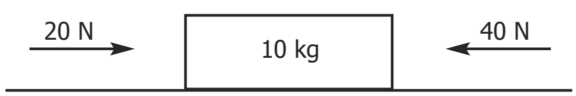
Name: ____

7. An object has an initial velocity that is negative. If the acceleration of the object is positive, how will velocity be affected?
   a. Velocity will decrease.
   b. Velocity will increase.
   c. Velocity will be constant.
   d. Velocity will either increase or decrease.

8. Galileo proposed a thought experiment where a sphere would be rolled down a U-shaped incline. In an “ideal scenario,” the sphere would move along the incline until it returned to its original height. Why will this not occur in real life?
   a. The force of gravity prevents the sphere from moving upward.
   b. The friction between the sphere and the incline reduces the sphere’s energy.
   c. The momentum of the sphere increases as it moves, causing it to rise above its original height.
   d. The sphere experiences a second collision with the incline, reducing its velocity.

9. Newton’s third law of motion states the following:
   a. An object at rest will remain at rest unless acted on by an unbalanced force.
   b. For every action there is an equal and opposite reaction.
   c. Moving objects will remain in motion until acted on by an unbalanced force.
   d. The greater an object’s mass, the greater the force needed to accelerate the object.

Use the following diagram to answer questions 10, 11, and 12.



10. What is the net force acting on the object?
    a. +20 N
    b. +40 N
    c. –20 N
    d. -60 N

11. How quickly is the object accelerating?
    a. $-2\ m/s^2$
    b. $+4\ m/s^2$
    c. $-4\ m/s^2$
    d. $+2\ m/s^2$

12. If the object starts from rest, what velocity will it reach after 5 seconds?
    a. +20 m/s
    b. +10 m/s
    c. –10 m/s
    d. –20 m/s

13. Which of the following objects has the greatest momentum?
    a. a statue bolted to the ground
    b. a teenager walking on the sidewalk
    c. a bicycle moving at 10 m/s
    d. a car driving at 5 km/h

14. Impulse is the product of
    a. mass and velocity
    b. force and time
    c. acceleration and energy
    d. displacement and speed

15. Which driving surface would provide the greatest friction?
    a. ice
    b. wet concrete
    c. dry pavement
    d. steel

16. Which of the following is ***not*** an example of energy conversion in a car crash?
    a. leaking engine fluid
    b. crumpled bumpers
    c. skid marks on the road
    d. loud noises

Name: ____

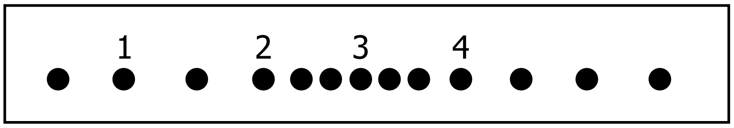
17. A rolling bowling ball has a momentum of 500 kg-m/s. What impulse will it apply to the bowling pin it strikes?
    a. 250 N-s
    b. 500 N-s
    c. 1000 N-s
    d. 100 N-s

18. A second collision occurs
    a. when passengers in a collision collide with their own vehicle
    b. when two cars collide with each other
    c. when two objects scrape against each other, reducing velocity
    d. when a moving vehicle collides with a stationary object

19. A crane lifts a set of steel girders to the upper floor of a construction site. What type of energy do the girders contain when they stop at the upper floor?
    a. kinetic energy
    b. thermal energy
    c. potential energy
    d. spring energy

20. The crane in question 19 breaks and the girders fall to the earth. What type of energy do the girders contain just before they hit the ground?
    a. kinetic energy
    b. thermal energy
    c. potential energy
    d. charge energy

On the following tickertape, each dot represents the distance an object travelled after 1 second. Use the diagram to answer questions 21 and 22.



21. Describe the motion of the object.
    a. The object is speeding up, and then slowing down.
    b. The object is slowing down, and then speeding up.
    c. The object's motion is uniform.
    d. None of the above.

22. At what point does the object have the greatest momentum?
    a. Point 1
    b. Point 2
    c. Point 3
    d. Point 4

23. Finding the slope on a velocity-time graph would allow you to determine
    a. velocity
    b. speed
    c. acceleration
    d. displacement

24. What is the relationship between reaction time and braking distance?
    a. When reaction time increases, braking distance decreases.
    b. When reaction time increases, braking distance increases.
    c. When reaction time decreases, braking distance increases.
    d. Reaction time does not affect braking distance.

25. In an accident, the distance a passenger is thrown from a moving car is related to
    a. the mass of the car
    b. the car's acceleration before the collision
    c. the size of the object that the car collides with
    d. the speed of the car before it collided with another object

Name: ____

Section 2: Explain

For this section, please explain your answers in detail and in complete sentences. For example, if the response is worth three marks, your answer should include at least three (3) important points that relate to the question. Where mathematical calculations are necessary, include all calculation steps in your answer(s). This will assist the tutor/marker in evaluating your complete solution. The mark allocations are provided for each question. This section of the final exam is worth 30 marks.

1. You are driving on dry pavement at 60 km/h. You are 85 metres from the next intersection when its traffic lights turn yellow.
   a. Are you able to stop your car before reaching the intersection? Assume your reaction time is 3 seconds and the frictional constant of dry pavement is 0.06. Show all calculations. (*6 marks*)

b. How would your braking distance be affected if you had travelled twice as fast? (*3 marks*)

____

c. How could you improve your reaction time while driving? Give two examples. (*2 marks*)

2. A bicycle and a car both drive over some broken glass and get flat tires. Luckily, both are only 50 m from a repair shop.

a. Which vehicle—the car or the bicycle—will be easier to push into the shop? Use Newton's laws of motion to explain why. (*2 marks*)

b. The driver pushes and forces his car to move. It accelerates at a rate of 3 m/s^2. If the car has a mass of 600 kg, how much force is he applying to his vehicle? Show all calculations. (*2 marks*)

3. Define impulse. Use impulse to explain how the air bags in a car reduce injuries in a vehicle collision. (*3 marks*)

Name: ____

4. Use the concept of inertia to explain why it is important to wear a seat belt when in a moving vehicle. (*5 marks*)

5. Elaine is watching the Canada Day fireworks display at The Forks. What are four different types of energy involved in a fireworks rocket? (*4 marks*)

6. Calculate the total braking distance for a car travelling at 60 km/h on a rain-soaked road (where k = 0.10). (*3 marks*)

Part B: Weather Dynamics

Section 1: Multiple Choice

Choose the best answer. Each question is worth one mark. This section of the final exam is worth 25 marks.

1. The gas that is most abundant in Earth's atmosphere is
   a. hydrogen
   b. carbon dioxide
   c. nitrogen
   d. oxygen

2. How does life on Earth benefit from the ozone layer?
   a. The ozone layer prevents atmospheric gases from escaping into space.
   b. The ozone layer warms the lower levels of the atmosphere.
   c. The ozone layer absorbs harmful ultraviolet radiation from the Sun.
   d. The ozone layer breaks down greenhouse gases in the troposphere.

3. As you increase altitude in Earth's atmosphere
   a. air pressure increases and density decreases
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4. What change would occur if Earth's albedo increased?
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Name: ____

6. Humidity refers to
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7. Which of the following chemicals is a greenhouse gas?
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8. Which of the these is ***not*** a way that scientists use the information they get from ice core samples?
   a. Fossilized air bubbles help scientists figure out what gases were present in the atmosphere.
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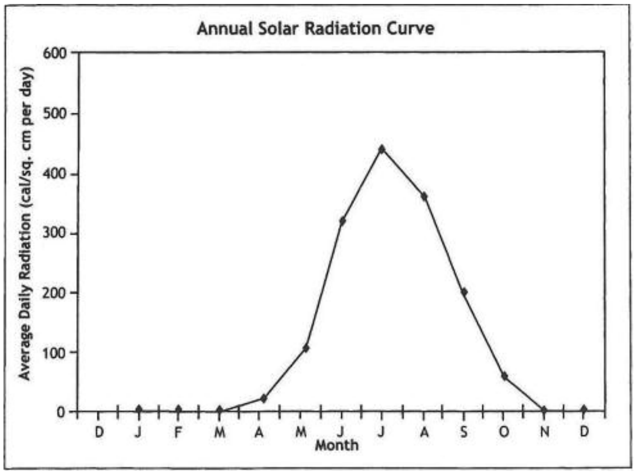

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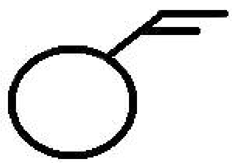

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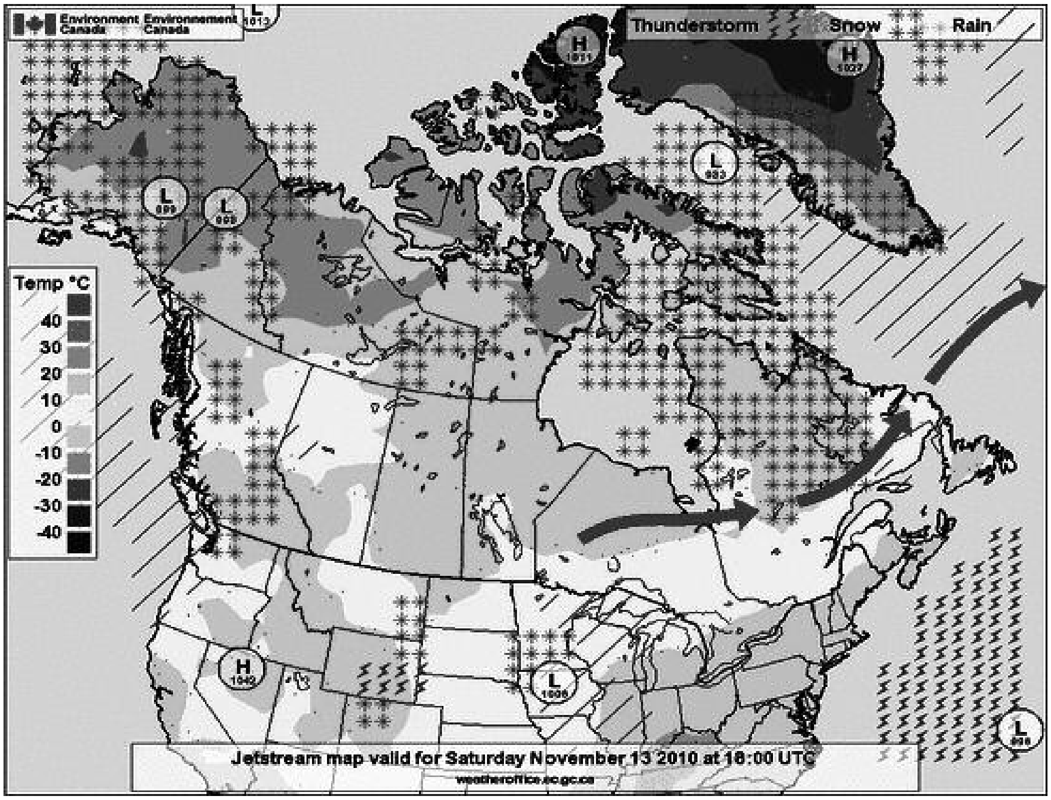
1. Describe how a thunderstorm is formed and how lightning results. (*6 marks*)

2. The following graphic was taken from the Environment Canada daily forecast website for November 13, 2010. (*4 marks*)



a. Use the graphic to identify the expected temperature range for the following areas:

i. southern Quebec (*1 mark*)

____

ii. northern Manitoba (*1 mark*)

____

b. Identify two provinces forecasted to receive snow. (*2 marks*)

____

____

Name: ________________________________

3. How is weather in the Prairie provinces predicted to change under a global warming scenario? Give three examples. (*3 marks*)

4. What evidence exists to suggest that Earth experiences natural cycles of warming and cooling? (*3 marks*)

5. How does radar work, and how can it be used to analyze weather patterns? (*4 marks*)

Grade 10 Science (20F)

Practice Final Examination

Answer Key

Grade 10 Science

Practice Final Examination
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 2.5 hours to write this exam.
- Supplies required: pencil or pen, eraser, paper, ruler—you are permitted to bring a calculator, but it is not required
- This exam covers course material from Modules 3 and 4.
- This exam is worth 20 percent of your final mark.

Part A: In Motion

Section 1: Multiple Choice

Choose the best answer. Each question is worth one mark. This section of the final exam is worth 25 marks.

1. Jackson travels 2 km north, then 3 km east, and finally 2 km south. Which statement is true?
   a. Jackson's displacement is 2 km west from his origin.
   b. Jackson is now 3 km east from where he started.
   c. Jackson's displacement is 7 km.
   d. None of the above.

DPSU-03-2014

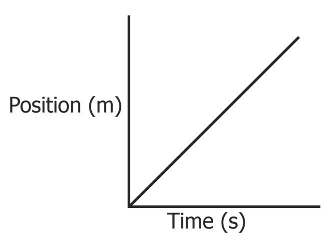
2. Velocity is a measure of
   a. change in position during a change in time
   b. the slope of a position-time graph
   c. displacement during an interval of time
   d. all of the above

3. Which of the following is a vector quantity?
   a. time
   b. velocity
   c. speed
   d. distance

4. A car at accelerates from 0 m/s to 25 m/s in 5 seconds. What is the average acceleration of the car?
   a. 30 m/s^2
   b. 50 m/s^2
   c. 125 m/s^2
   d. 5 m/s^2

5. Which scenario represents an instant of time?
   a. A long-distance runner crosses the finish line at 1 hour, 37 minutes.
   b. A businesswoman takes a two-hour flight from Winnipeg to Montreal.
   c. An ambulance drives for two minutes to arrive at the scene of an accident.
   d. A student leaves home at 8:15 and gets to school at 8:30.

6. What does the following position-time graph tell us about the motion of the object?



   a. The object is accelerating in the positive direction.
   b. The object is moving in the positive direction at a constant velocity.
   c. The object is in uniform motion and headed in the negative direction.
   d. The object is not moving.

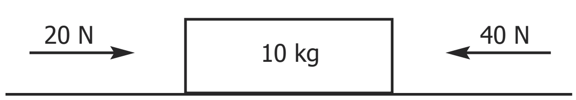
Name: ____

7. An object has an initial velocity that is negative. If the acceleration of the object is positive, how will velocity be affected?
   a. Velocity will decrease.
   b. Velocity will increase.
   c. Velocity will be constant.
   d. Velocity will either increase or decrease.

8. Galileo proposed a thought experiment where a sphere would be rolled down a U-shaped incline. In an "ideal scenario," the sphere would move along the incline until it returned to its original height. Why will this not occur in real life?
   a. The force of gravity prevents the sphere from moving upward.
   b. The friction between the sphere and the incline reduces the sphere's energy.
   c. The momentum of the sphere increases as it moves, causing it to rise above its original height.
   d. The sphere experiences a second collision with the incline, reducing its velocity.

9. Newton's third law of motion states the following:
   a. An object at rest will remain at rest unless acted on by an unbalanced force.
   b. For every action there is an equal and opposite reaction.
   c. Moving objects will remain in motion until acted on by an unbalanced force.
   d. The greater an object's mass, the greater the force needed to accelerate the object.

Use the following diagram to answer questions 10, 11, and 12.



10. What is the net force acting on the object?
   a. +20 N
   b. +40 N
   c. –20 N
   d. -60 N

11. How quickly is the object accelerating?
    a. –2 m/s²
    b. +4 m/s²
    c. –4 m/s²
    d. +2 m/s²

12. If the object starts from rest, what velocity will it reach after 5 seconds?
    a. +20 m/s
    b. +10 m/s
    c. –10 **m/s**
    d. –20 m/s

13. Which of the following objects has the greatest momentum?
    a. a statue bolted to the ground
    b. a teenager walking on the sidewalk
    c. a bicycle moving at 10 m/s
    d. a car driving at 5 km/h

14. Impulse is the product of
    a. mass and velocity
    b. force and time
    c. acceleration and energy
    d. displacement and speed

15. Which driving surface would provide the greatest friction?
    a. ice
    b. wet concrete
    c. dry pavement
    d. steel

16. Which of the following is ***not*** an example of energy conversion in a car crash?
    a. leaking engine fluid
    b. crumpled bumpers
    c. skid marks on the road
    d. loud noises

Name: ____

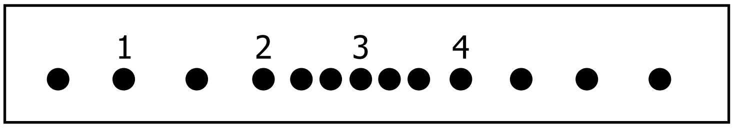
17. A rolling bowling ball has a momentum of 500 kg-m/s. What impulse will it apply to the bowling pin it strikes?
    a. 250 N-s
    b. 500 N-s
    c. 1000 N-s
    d. 100 N-s

18. A second collision occurs
    a. when passengers in a collision collide with their own vehicle
    b. when two cars collide with each other
    c. when two objects scrape against each other, reducing velocity
    d. when a moving vehicle collides with a stationary object

19. A crane lifts a set of steel girders to the upper floor of a construction site. What type of energy do the girders contain when they stop at the upper floor?
    a. kinetic energy
    b. thermal energy
    c. potential energy
    d. spring energy

20. The crane in question 19 breaks and the girders fall to the earth. What type of energy do the girders contain just before they hit the ground?
    a. kinetic energy
    b. thermal energy
    c. potential energy
    d. charge energy

On the following tickertape, each dot represents the distance an object travelled after 1 second. Use the diagram to answer questions 21 and 22.



21. Describe the motion of the object.
    a. The object is speeding up, and then slowing down.
    b. The object is slowing down, and then speeding up.
    c. The object's motion is uniform.
    d. None of the above.

22. At what point does the object have the greatest momentum?
    a. Point 1
    b. Point 2
    c. Point 3
    d. Point 4

23. Finding the slope on a velocity-time graph would allow you to determine
    a. velocity
    b. speed
    c. acceleration
    d. displacement

24. What is the relationship between reaction time and braking distance?
    a. When reaction time increases, braking distance decreases.
    b. When reaction time increases, braking distance increases.
    c. When reaction time decreases, braking distance increases.
    d. Reaction time does not affect braking distance.

25. In an accident, the distance a passenger is thrown from a moving car is related to
    a. the mass of the car
    b. the car's acceleration before the collision
    c. the size of the object that the car collides with
    d. the speed of the car before it collided with another object

Name: ____

Section 2: Explain

For this section, please explain your answers in detail and in complete sentences. For example, if the response is worth three marks, your answer should include at least three (3) important points that relate to the question. Where mathematical calculations are necessary, include all calculation steps in your answer(s). This will assist the tutor/marker in evaluating your complete solution. The mark allocations are provided for each question. This section of the final exam is worth 30 marks.

1. You are driving on dry pavement at 60 km/h. You are 85 metres from the next intersection when its traffic lights turn yellow.
   a. Are you able to stop your car before reaching the intersection? Assume your reaction time is 3 seconds and the frictional constant of dry pavement is 0.06. Show all calculations. (*6 marks*)

      (*1 mark*) Convert your units of velocity into m/s.
      (60 km /h) x (1000 m/km) x (1 h/3600 s) = 16.7 m/s

      (*2 marks*) Calculate the distance travelled while you react.
      Reaction Distance = velocity x reaction time
      Reaction Distance = 16.7 m/s x 3 s
      Reaction Distance = 50.1 m

      (*2 marks)* Calculate the distance travelled while you brake.
      Braking Distance = frictional constant x velocity^2
      Braking Distance = 0.06 x (16.7 m/s)^2
      Braking Distance = 16.7 m

      (*1 mark*) Calculate the total stopping distance.
      Stopping Distance = Reaction Distance + Braking Distance
      Stopping Distance = 50.1 m + 16.7 m
      Stopping Distance = 66.8 m

      Yes, you are capable of stopping your car before the intersection.

b. How would your braking distance be affected if you had travelled twice as fast? (*3 marks*)

16.7 m/s x 2 = 33.4 m/s

Braking Distance = frictional constant x velocity^2
Braking Distance = 0.06 x (33.4 m/s)^2
Braking Distance = 66.9336 m → 66.9 m

66.9 m/16.7 m = 4.005 → 4.0

If you travelled twice as fast, then your braking distance would be four times as long.

c. How could you improve your reaction time while driving? Give two examples. (*2 marks*)

- **Make sure you are alert and fully awake when driving.**
- **Get rid of any distractions from the road, such as handling food, makeup, cell phones, or CD player and radio controls.**
- **Do not drive after drinking alcohol, depressant drugs, or medications that cause drowsiness.**

2. A bicycle and a car both drive over some broken glass and get flat tires. Luckily, both are only 50 m from a repair shop.

a. Which vehicle—the car or the bicycle—will be easier to push into the shop? Use Newton's laws of motion to explain why. (*2 marks*)

- **Newton's second law of motion states that objects with greater mass require a greater force to accelerate from rest.**
- **The bicycle will be easier to push into the repair shop because it has much less mass than the car.**

b. The driver pushes and forces his car to move. It accelerates at a rate of 3 m/s^2. If the car has a mass of 600 kg, how much force is he applying to his vehicle? Show all calculations. (*2 marks*)

(*1 mark*) **Force = mass x acceleration**
(*0.5 mark*) **Force = 600 kg x 3 m/s^2**
(*0.5 mark*) **Force = 1800 N**

The driver is pushing on his car with a force of 1800 N.

Name: ____

3. Define impulse. Use impulse to explain how the air bags in a car reduce injuries in a vehicle collision. (*3 marks*)
   - **Impulse is a force applied over an interval of time. It can be represented by the formula $I = F(\Delta t)$.**
   - **In a vehicle collision, a car is struck by a large force in a very short instant of time.**
   - **Air bags inflate upon impact and provide a barrier between the driver and the steering wheel. They increase the amount of time it takes for the second collision to occur, which decreases the force and severity of injuries.**

4. Use the concept of inertia to explain why it is important to wear a seat belt when in a moving vehicle. (*5 marks*)
   - **Inertia is the tendency of an object to resist changes to its motion.**
   - **When a vehicle is in motion, all of its passengers are moving with the same velocity as the vehicle.**
   - **When the vehicle slows down, the passengers inside the car do not slow down at the same rate. Their inertia causes them to continue moving with the same velocity.**
   - **If you are unrestrained while in a vehicle, when it stops you will continue moving forward until you collide with something—such as the dashboard or steering wheel. If the vehicle stops quickly, you could seriously hurt yourself.**
   - **A seat belt will catch your body as it moves forward, reducing your inertia.**

5. Elaine is watching the Canada Day fireworks display at The Forks. What are four different types of energy involved in a fireworks rocket? (*4 marks*)
   - **The rocket displays kinetic energy as it launches into the sky.**
   - **When fireworks explode, they release light energy and sound energy.**
   - **The burst of fireworks also releases heat energy.**

6. Calculate the total braking distance for a car travelling at 60 km/h on a rain-soaked road (where $k = 0.10$). (*3 marks*)

   60 km/h = 60/(3.6 m/s) = 16.7 m/s

   $d = kv^2$
   $d = (0.10)(16.7 \text{ m/s})^2$
   $d = 27.889 \text{ m} \rightarrow 27.9 \text{ m}$

   The total braking distance is 27.9 metres.

Part B: Weather Dynamics

Section 1: Multiple Choice

Choose the best answer. Each question is worth one mark. This section of the final exam is worth 25 marks.

1. The gas that is most abundant in Earth's atmosphere is
   a. hydrogen
   b. carbon dioxide
   c. nitrogen
   d. oxygen

2. How does life on Earth benefit from the ozone layer?
   a. The ozone layer prevents atmospheric gases from escaping into space.
   b. The ozone layer warms the lower levels of the atmosphere.
   c. The ozone layer absorbs harmful ultraviolet radiation from the Sun.
   d. The ozone layer breaks down greenhouse gases in the troposphere.

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   a. air pressure increases and density decreases
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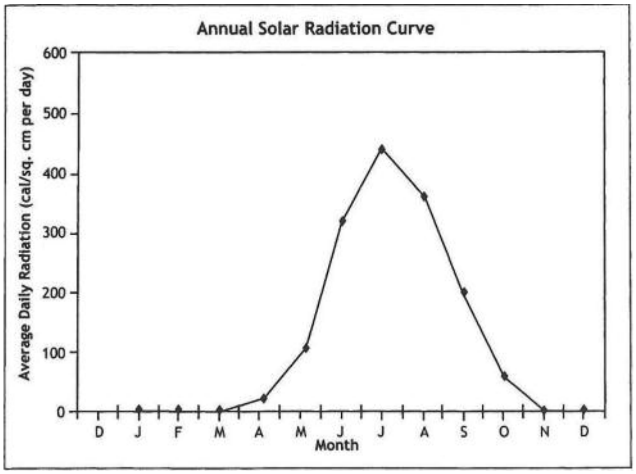

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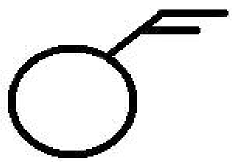

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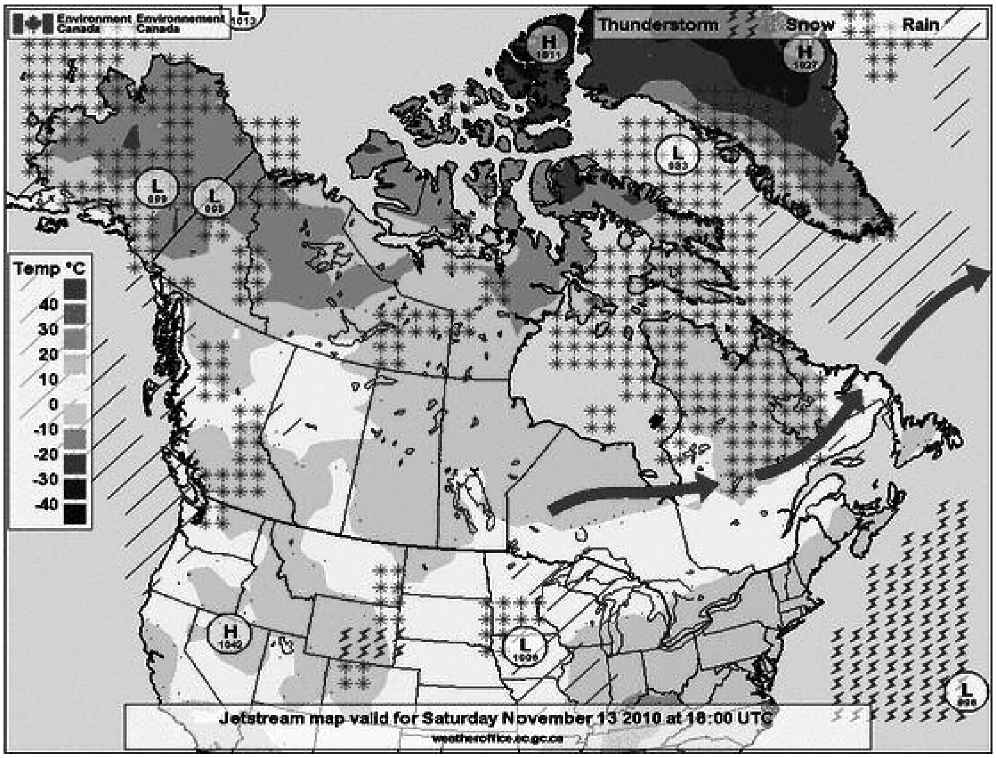
1. Describe how a thunderstorm is formed and how lightning results. (*6 marks*)
   - **A hot sunny day will cause water vapour from Earth to rise and cool into water droplets.**
   - **A large amount of water vapour cooling will build up enormous clouds with tightly packed water droplets near the base.**
   - **If the rising moist air is strong enough, the water vapour gets pushed very high.**
   - **Lightning is the result of the rapidly moving cloud particles being rubbed against each other so much that electrical charges occur.**
   - **The particles become loaded with extra negative charges.**
   - **When this negatively charged cloud passes over anything that is positively charged, the negative charges (electrons) want to leave the cloud and jump to the positively charged object.**

2. The following graphic was taken from the Environment Canada daily forecast website for November 13, 2010. (*4 marks*)



Graphics courtesy of Environment Canada. All rights reserved.

a. Use the graphic to identify the expected temperature range for the following areas:
   i. southern Quebec (*1 mark*) **0° C to 10° C**
   ii. northern Manitoba (*1 mark*) **0° C to –10° C (or 10° C to 20° C)**

b. Identify two provinces forecasted to receive snow. (*2 marks*)
   Student identifies any two of the following: British Columbia, Quebec, Yukon, Northwest Territories, or Nunavut.

3. How is weather in the Prairie provinces predicted to change under a global warming scenario? Give three examples. (*3 marks*)
   - **Increased temperatures will increase evaporation, intensifying drought conditions.**
   - **Soil moisture will become more variable.**
   - **There will be a longer growing season.**
   - **There will be decreased snow cover and earlier spring runoff.**
   - **There will be a greater number of extreme weather-related events.**

Name: ____

4. What evidence exists to suggest that Earth experiences natural cycles of warming and cooling? (*3 marks*)
   - **Polar ice generally remains frozen year-round, growing in layers with each year of snowfall.**
   - **Researchers have drilled into the polar ice caps to examine the dust and air collected in these layers of ice.**
   - **Examining these ancient particles assists researchers in estimating the volcanic activity that took place over the last 500,000 years.**

5. How does radar work, and how can it be used to analyze weather patterns? (*4 marks*)
   - **Radar transmits microwaves. When these microwaves strike an object they will be reflected back toward the radar transmitter.**
   - **The strength of the reflected microwaves can be used to determine the distance between the transmitter and the object struck by the waves.**
   - **Radar pointed into the atmosphere can be made to strike small particles such as snow, hail, or rain.**
   - **The microwaves reflected by precipitation can be used to determine the location and strength of the precipitation.**

Grade 10 Science (20F)

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IN MOTION

A Learning Resource for Students

Don Metz, Ph.D.

Manitoba Public Insurance

Manitoba

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Manitoba Public Insurance (MPI) and the Government of Manitoba, Department of Education and Youth gratefully acknowledge the contribution and support of all the specialists from the various stakeholder agencies who assisted with this project.

This module is intended to assist students in achieving the learning outcomes for the Manitoba Senior 2 Science 20F "In Motion" content cluster. It provides for a road safety context to topics in kinematics and dynamics.

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Chapter 1

Introduction

At times, life can be a blur, everything moves by quickly, and people and machines are constantly on the go. Our understanding of motion is important in our everyday lives, especially as our modes of transportation become increasingly more sophisticated.

FIGURE 1

CLASS ACTIVITY:

Tapping into Prior Knowledge

What do YOU know about motion? Use a rotational graffiti activity and the following questions to express your ideas about motion.

Think About IT!

1. What does it mean to move? How does an object move? Give examples.
2. What skills and abilities do you need to drive a car?
3. What happens in a car crash?
4. Is stunt car driving or NASCAR driving dangerous?

FIGURE 2

Discuss your ideas about motion with your group and with your class. Have you ever been in a car collision? Do you know anyone who has been in a car collision?

Rotational Graffiti

The class is divided into groups of three and each group is given a large piece of newsprint (24" x 36" works nicely and is available in pads from office supply stores). Write each of the questions above on the top of separate pieces of newsprint. Each question is repeated on another newsprint with the word "DRAW" added. Using coloured markers, each group has one minute to put their ideas onto the page. At the end of every minute the teacher calls out "rotate" and the students pass their newsprint onto the next group. When the groups have addressed each question twice (one written response and one drawing response), they post their results on the wall for discussion.

Car Crash – Who is to Blame?

Car collisions have serious consequences. People are injured, families lose their loved ones, and vehicles, property, and the environment are damaged. In some cases, irresponsible persons are sued or charged with dangerous driving, or even vehicular manslaughter. The responsibility belongs to everyone.

However, it is not always easy to determine responsibility for a car collision. The collision often happens extremely rapidly and individual observations and memories of the collision can vary.

CLASS ACTIVITY:

What do you think of the following car crash scenario? In your group, discuss events that might have led to the collision. Review the evidence and see if you can reconstruct the crash. Each group should present their findings to the class.

Car Crash Scene

Figure 3 shows a traffic scene moments before an accident is about to occur. Car A is travelling east at a constant velocity and is just about to enter the intersection. Car B is moving south with its right turn signal on and a motorcycle is close behind Car B. A skateboarder is crossing the intersection in the easterly direction. All of the individuals involved agreed that these were their positions before the collision. However, they could not remember any specifics about markings on the road.

Figure 4 shows the traffic scene moments after the accident. Each individual told their story in the accident reports that they filed at the police station.

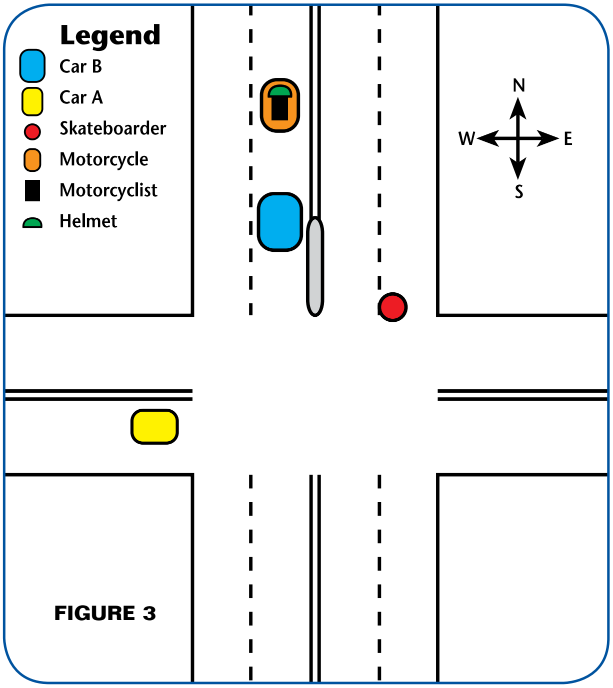


FIGURE 3

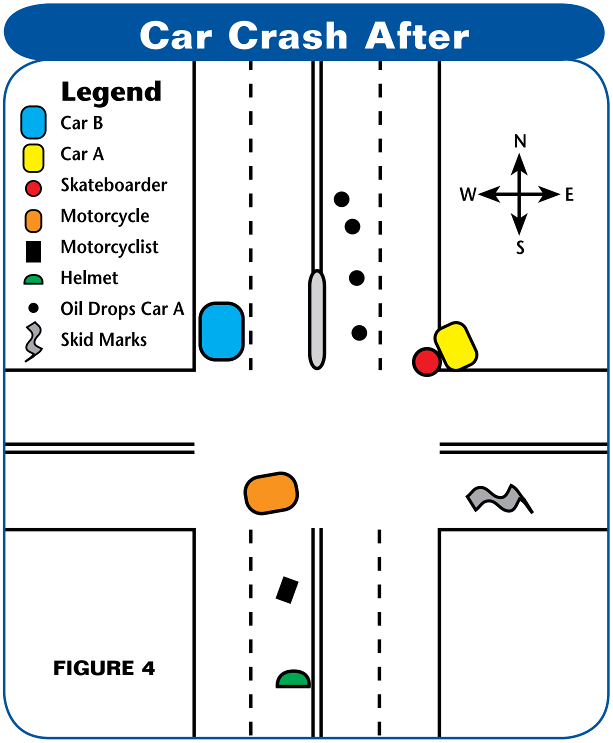
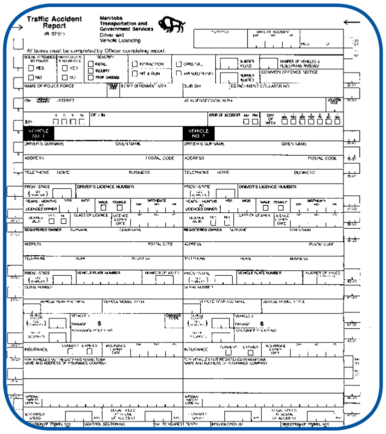


FIGURE 4

FIGURE 5



Accident Report – Driver of Car A

"My car was travelling east at a constant velocity. As I approached the intersection the light turned green so I kept going through the intersection at the same speed. Then, I heard a loud bang and my car spun to the left carrying it into the pedestrian walkway on the perpendicular street past the skateboarder. My car ended up jumping the curb on the far side of the corner. I wasn't injured but everything took place so quickly I'm not entirely sure what happened."

Accident Report – Driver of Car B

"I was driving south on Main Street when I wanted to check the name of the next street. So I signalled and moved from the median lane to the curb lane. I don't know whether the signal lights were red or green or yellow as I was trying to read the street sign."

Accident Report – Skateboarder

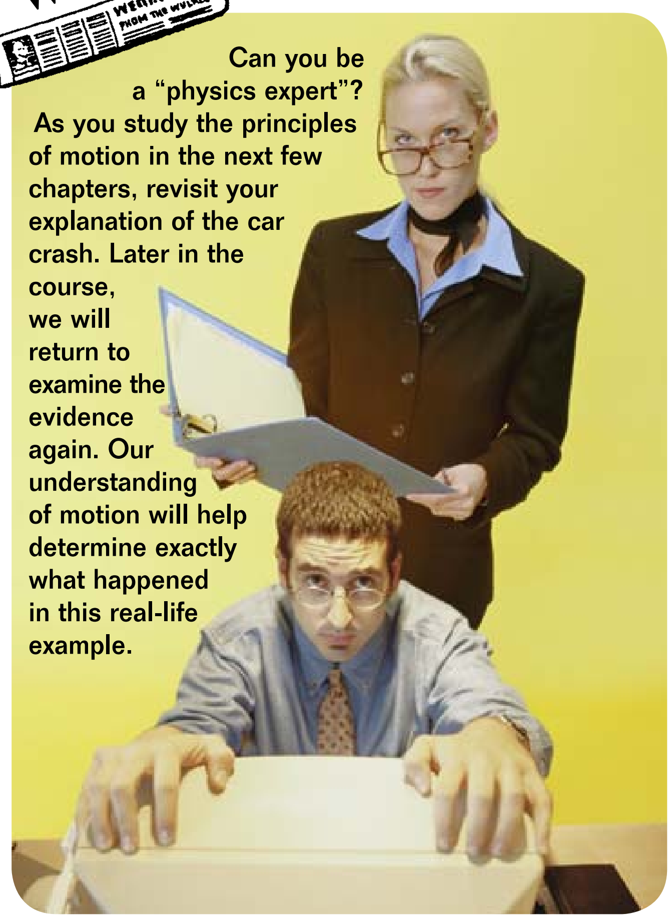
"I was boarding east along the pedestrian walkway with my walkman on so I didn't hear any sounds. I wasn't paying much attention to the traffic when suddenly Car A spun into the walkway. I bailed and my board collided with the rear portion of Car A. I wasn't hurt but I don't listen to the walkman anymore when I'm riding."

Accident Report – Motorcyclist

"I was travelling south and had the green light. As Car B took the curb lane I signalled for a left turn then proceeded cautiously into the intersection to complete my turn. Car A ran a red light and was making a left turn when I collided with the front end of her car. I was thrown over the hood of the car and landed in the street. My helmet was not securely tied and it flew off my head on impact. I suffered a concussion and remained in the hospital for several days."

Police Report

Front end damage was extensive to the motorcycle. Car A had damage on the front and back fenders. The driver of Car A claimed that the damage on the front end of the car was from a previous fender bender. The motorcyclist claimed that he made the damage on the front end of Car A and that the skateboard damaged the rear of Car A. Oil drops, skid marks, and the motorcyclist's helmet were found in the locations marked in Figure 4. The driver of Car A and the motorcyclist have conflicting stories concerning who was responsible for the accident. Therefore, we recommend that a "physics expert" be approached to investigate each driver's claim.



Chapter 2

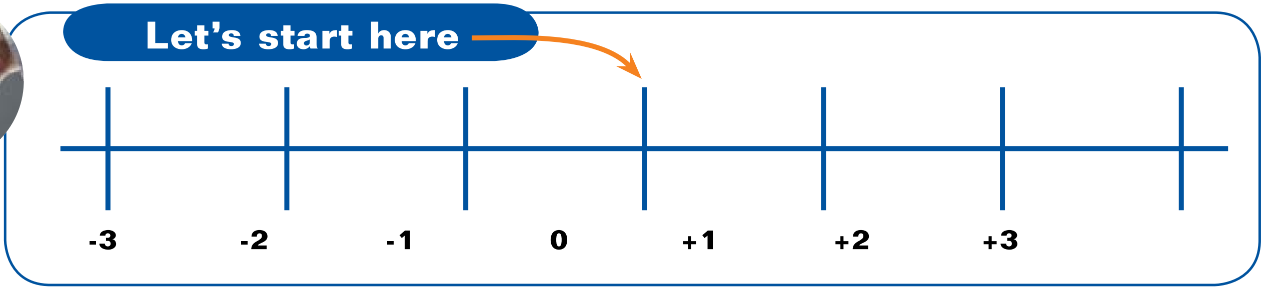
Analyzing Motion

Position and Displacement

What does it mean to move? First of all, if you stay in one place without changing your position, we would say you are standing still. You're not moving!

In order to move, you must change your position. So, get off the couch and move!

If you want to describe the movement of an object (for example, a person running or a vehicle in motion), you must be able to describe its position. In order to communicate our information to other persons, everyone must agree on a reference point, called the origin, from which we begin to take measurements. Position is the distance and direction an object is located from an origin.

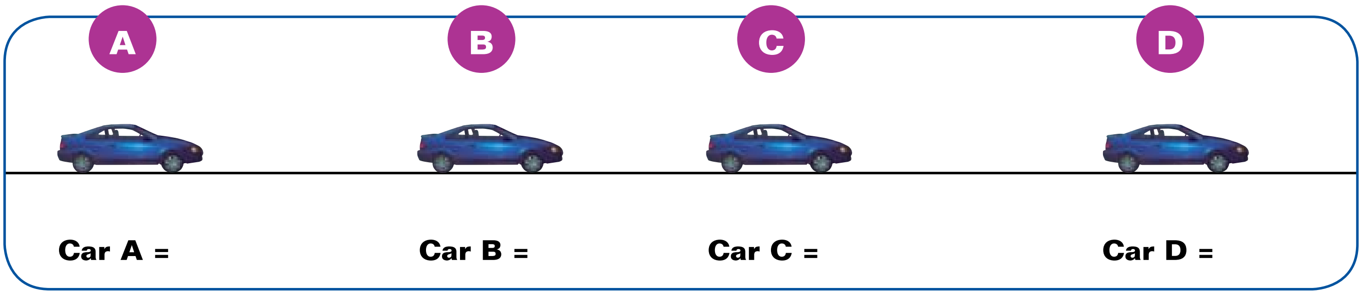


We can easily describe distance by measuring from the origin with a ruler. Direction can be reported in many ways. It is common to use a coordinate line, that is, a line labelled -3, -2, -1, 0, +1, +2, +3 with the origin at 0, as shown in the diagram above. In this case, we use the plus sign (+) to indicate a position to the right of the origin and a minus sign (-) to indicate a position left of the origin. There are other ways to describe direction. For instance, we could use a compass or a direction finder (north, south, east, west).

In this course, we will make describing direction very easy by restricting our motion along a single straight line. In this way, you can describe motion using a coordinate line or by using common terms like right and left, forward and backward, or, if your line is vertical, up and down. Any quantity that is described using magnitude and direction is called a vector quantity. In this text, when vector quantities are represented in symbolic form, they will be **bolded**.

PRACTICE

1. In the following diagram, use the front bumper of Car B as your origin. Then, using a ruler, record in your notebook the position in cm of Cars A, C and D.



Displacement

Remember that in order to move an object, we must change the object's position. Any change in position is called a displacement. Along a straight line, the displacement is found by the final position minus the initial position. We can write this expression as:

displacement = position 2 - position 1

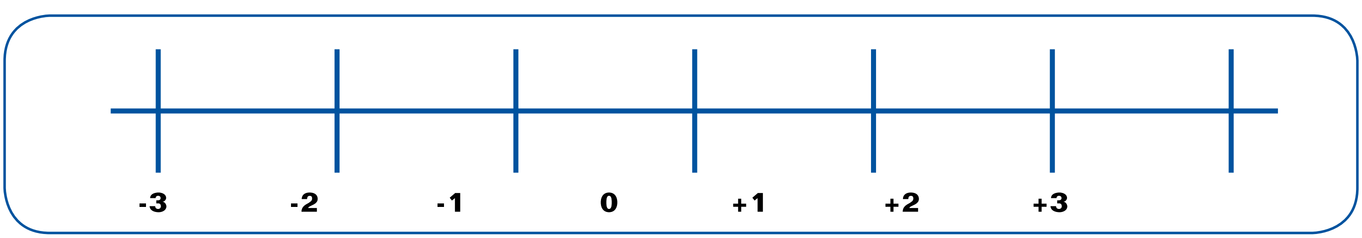
or in SYMBOLIC FORM

$$\Delta\mathbf{d} = \mathbf{d}_2 - \mathbf{d}_1$$

where d stands for the position and Δ (delta) means "change in". Therefore Δd reads "change in position" or simply displacement. The **bold** font designates a vector quantity, which means a direction must be reported.

Example:

A toy car moves across a table in a straight line. A number line is marked on the table and the initial position of the car is -1 cm. If the car stops at the +3 cm mark, calculate the displacement of the car.



$\mathbf{d}_1$ = -1 cm
and
$\mathbf{d}_2$ = +3

$\Delta\mathbf{d} = \mathbf{d}_2 - \mathbf{d}_1$
$\Delta\mathbf{d} = (+3) - (-1)$
$\Delta\mathbf{d}$ = **+4 cm** (verify by counting spaces on the number line)

PRACTICE

1. The following data represent the initial (d_1) and final (d_2) positions of a car, bicycle, pedestrian, and skateboarder.

	Car	Bicycle	Pedestrian	Skateboarder
d_1	+2 m	+7 m	-1 m	+4 m
d_2	+14 m	+2 m	+2 m	-1 m

a) Draw a number line and label an origin as point “0”. Mark the initial position of each object above the line.

b) Mark the final position of each object below the number line.

c) Calculate the displacement of each object.

d) What is happening? If each displacement takes place in the same period of time, write a paragraph to describe the motion of each object.

2. The dispatcher of a courier service receives a message from Truck A that reports a position of +5 after a displacement of +2. What was the initial position of Truck A? First solve the problem using a number line, and then solve the problem using an equation.

3. Two taxis are travelling along Pembina Highway in opposite directions. Taxi A changes its position from +6 to +10 during the same time as Taxi B moves from +6 to +1. Draw a diagram to show the initial and final positions of each taxi.

4. Calculate the displacements of each taxi in question #3.

5. What can you conclude about the speed of the taxis?

6. How would the position of the taxis change if you decided to move your origin? How does the displacement of the taxis change if you decide to move your origin?

Instants and Intervals of Time

We know that cars move at different speeds; they speed up and slow down. In the previous taxi example, we know that Taxi B was moving faster because it travelled a greater distance in the same period of time as Taxi A. However, we still do not know the speed of the taxi. Was traffic moving slowly or quickly?

An instant of time is a reading on a clock, such as 10:15 or 36.2 seconds. In order to know how fast an object is moving, we need to know the time it took for the car to move from one position to another (change in time). An interval of time is the difference between two such clock readings. Thus,

Interval of time = time 2 - time 1

or in SYMBOLIC FORM

$$\Delta t = t_2 - t_1$$

Reminder

"Δ" means "Change in"

Time is a quantity for which direction is not required. Quantities that describe magnitude only are called **scalars**.

In order to answer the question "How fast is the taxi going?", we need to collect information about the position of the taxi at different points in time.

Think About IT!

1. **Describe several real-life examples of an interval of time.**
2. **Determine how many hours is an interval of 10 seconds? What made this calculation a difficult one for you?**

Investigation #1 VEHICLES IN MOTION

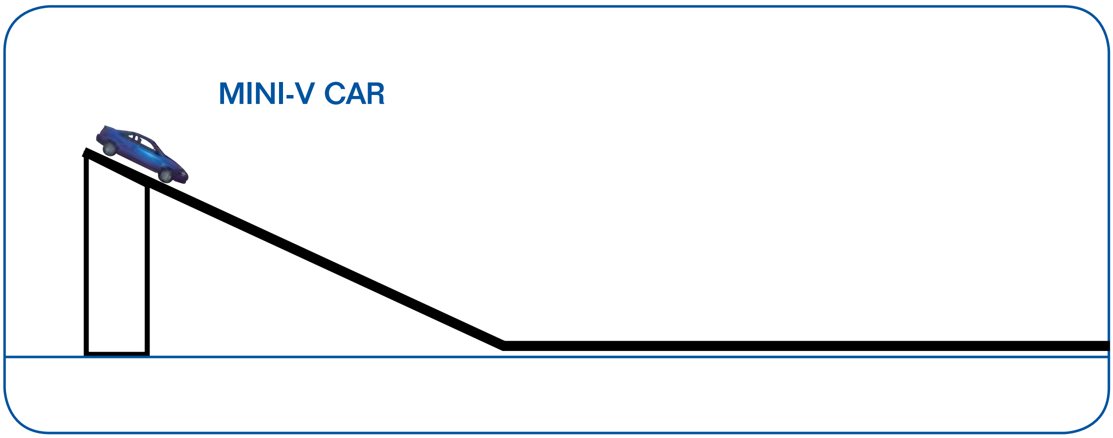
In this activity, you can use a diecast toy car as a miniature vehicle (let's call it a "mini-V"!). Make sure you choose your fastest mini-V car. A marble or steel bearing also works very well.

Procedure

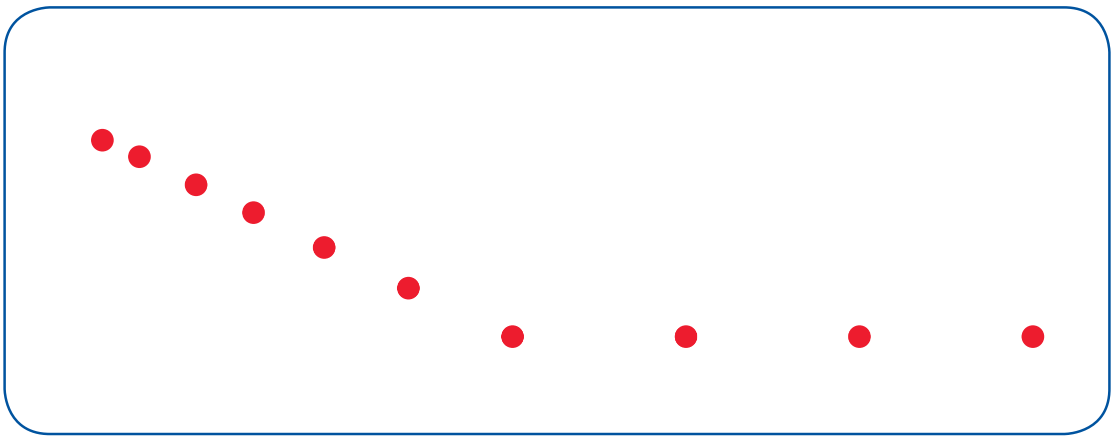
1. Set up a ramp as shown in the diagram. The ramp should be at least 1 m long.

2. Videotape the motion of a mini-V car as it moves down the ramp and across the table. Place the camera about 3 - 4 m away and do not move the camera when you tape the motion.

3. Place an acetate sheet (clear plastic like an overhead sheet) on the television screen and replay the video using the frame by frame advance feature. At each frame or two, mark the position of the mini-V car on the acetate using a marking pen (make a small dot at the same place on the car each time). DO NOT MARK THE TV SCREEN!



Your results should look something like this.



Think About IT!

1. When is the car moving the slowest? Explain.
2. When is the car moving the fastest? Explain.
3. Why do the spaces not change as the car moves across the table?
4. What do you conclude about the motion of the car on the ramp compared to the motion of the car across the table?

Uniform Motion

On most highways there is a posted speed limit. (Do you know what the speed limit is if no sign is posted?) Cars that travel down the highway at this speed are said to be moving in uniform motion. That is, their motion is constant. A picture of Car A travelling down a highway at a constant speed is shown in Diagram A. Each frame represents a picture of the car at one-second intervals. Notice that the spaces are equal for equal time intervals. Measure the distance between each interval and complete Table A. Graph your results with the position on the y axis and the time on the x axis. Repeat the procedure using measurements from Diagram B and answer the questions.

Diagram A

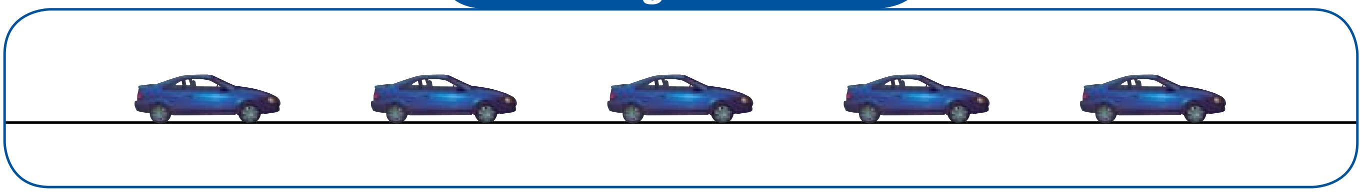


Diagram B

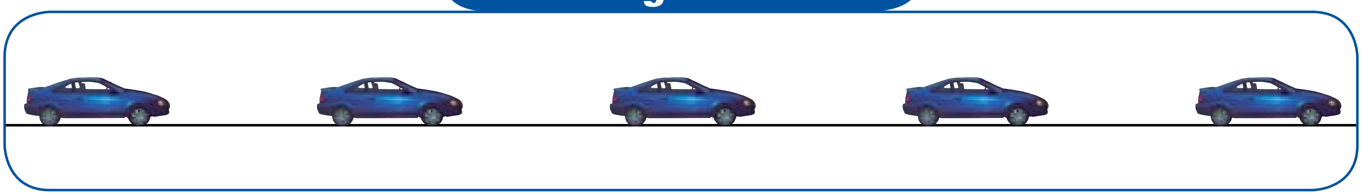


Table A

Position (cm)	Time (s)
	0
	1
	2
	3
	4
	5

Table B

Position (cm)	Time (s)
	0
	1
	2
	3
	4
	5

Think About IT!

1. What is the difference between Graph A and Graph B?
2. How do the spacings of the cars in the two diagrams compare to the plotted points on the graphs?

Slope

The spacings between the dots in our frame-by- frame analysis are reflected in the steepness of the line on the graphs. The steeper the line, the larger the spaces. That is, Car B travelled a greater distance in 1 second than Car A. In other words, Car B was going faster than Car A. “How fast” a car moves is called the speed of the car and is displayed on the car’s speedometer.

Velocity is the term physicists use to describe how fast and in what direction an object moves. Velocity is defined as:

$$\text{Velocity} = \frac{\text{Change in position}}{\text{Change in time}}$$

This definition is true for objects whose velocities are not changing. In real life, it is very difficult to find objects that move exactly uniformly, so we often assume that an object has a constant velocity even if it does vary somewhat. Consequently, we call this form the average velocity and in symbolic form we write:

$$\mathbf{v}_{avg} = \frac{\Delta \mathbf{d}}{\Delta t}$$

Velocity is a vector and always has a direction. In your answers, you can use common terms like right, left, forward and backward, or if you use a coordinate line, + or - signs.

The steepness of the line on the graph is called the slope of the line. The slope of any straight line (including the roof on your house!) is always constant. Numerically, this constant is the ratio of the rise (the vertical displacement (Δy)) and the corresponding run (the horizontal displacement (Δx)).

We can calculate slope by using the formula

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}}$$

or

$$\text{Slope} = \frac{\Delta y}{\Delta x}$$

(We will do this in detail on the next page).

In our motion example, the position (**d**) is on the y axis and time (t) is on the x axis. Therefore, the slope is $\Delta \mathbf{d}/\Delta t$. That is, the slope of the line is the velocity of the object.

Think About IT!

1. **Make a concept map to link the following terms together:**

- **slope,**
- **velocity,**
- **speed,**
- **$\Delta \mathbf{d}$,**
- **Δt,**
- **steepness,**
- **constant,**
- **displacement,**
- **rise,**
- **run.**

Include some terms of your own.

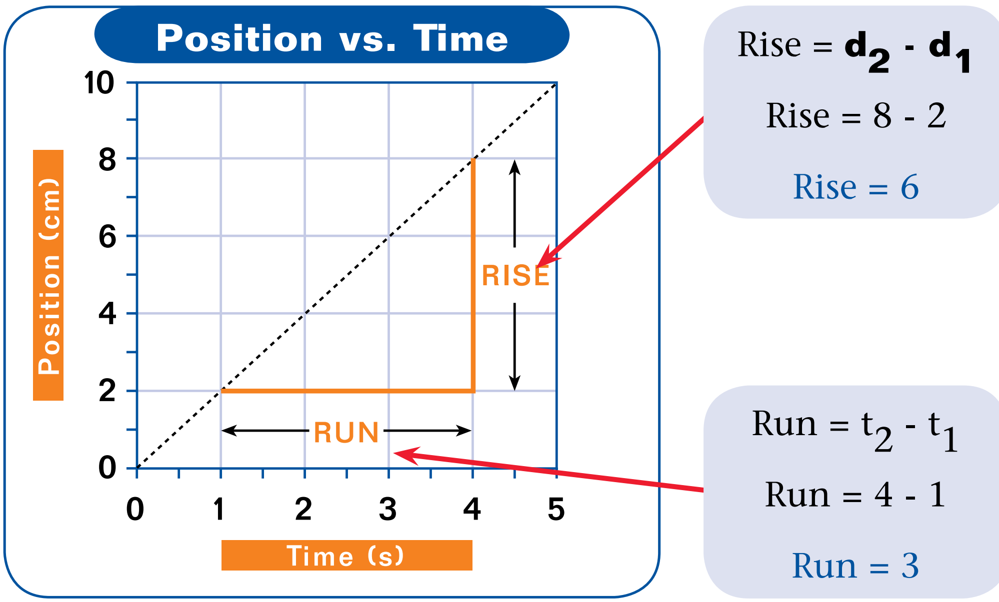
Calculating Slope

In order to calculate the slope, choose any two points on the straight line. Generally, to reduce errors in calculation, we choose two points that are reasonably far apart. Notice also from the position-time graph that:

$$\text{Rise} = \mathbf{d_2} - \mathbf{d_1} = \Delta \mathbf{d}$$

and the

$$\text{Run} = t_2 - t_1 = \Delta t$$



PRACTICE

1. For each of the following cases, sketch a diagram and label an origin and a direction on the diagram. Calculate the average velocity.

a) A bicycle travels 36 km in 1.2 h.

b) A person runs 17 m toward a bus stop in 2 seconds.

c) A car passes 6 telephone poles, each spaced 50 m apart, in 18 seconds.

d) A mini-V car moves along a track from +2 cm to +26 cm in 0.5 seconds.

2. For each example in question #1, comment from your personal experience on whether the object is moving slow, medium, fast, or has an unrealistic velocity.

3. A skateboarder is coasting at a velocity of 2 m/s away from the corner. If we let the corner be the origin, how far will the boarder travel in 3.5 seconds?

4. In terms of the displacement of a vehicle on a highway, what does speeding mean?

5. A mini-V car rolls off a ramp with a constant velocity of 1.5 m/s onto a horizontal track. The end of the ramp is at position -12 cm. If the car reaches the end of the track in 0.4 seconds find the length of the track. Include a diagram and label the origin.

Converting from m/s to km/h

Example: Convert 4.0 m/s to km/h

1 m = 0.001 km   4.0 m = 0.004 km

That is, divide metres by 1 000

1 h = 60 min and 1 min = 60 seconds

1 h = 60 x 60 = 3 600 seconds

$$1 \text{ second} = \frac{1}{3\,600} \text{ hour}$$

$$4.0 \text{ m/s} = \frac{\frac{4.0m}{1\,000}}{\frac{1s}{3\,600}} \text{ km/h}$$

AND

$$4.0 \text{ m/s} = \frac{4.0}{1} \times \frac{3\,600}{1\,000} \text{ km/h}$$

$$4.0 \text{ m/s} = \frac{4.0}{1} \times 3.6 \text{ km/h}$$

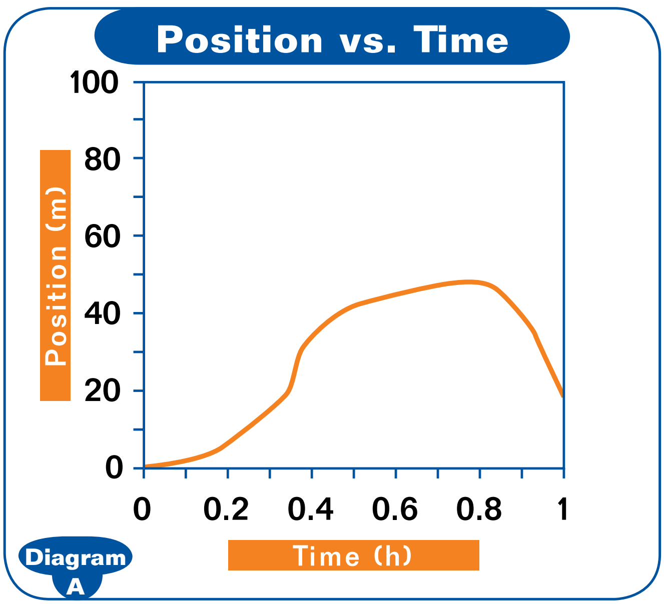
4.0 m/s = 14.4 km/h

Conversion Shortcut: To convert m/s to km/h just multiply m/s by 3.6!

Instantaneous Velocity

Average velocity describes the velocity of an object during an interval of time. Instantaneous velocity is the velocity at a specific time. For uniform motion, the instantaneous velocity is always the same as the average velocity, which is why we call it uniform. For uniform motion, the position-time graphs are straight lines. However, the position-time graphs for non-uniform motion are curves.

Diagram A is the position-time graph of object in non-uniform motion. Can you tell from the graph when the object is going slow or going fast?

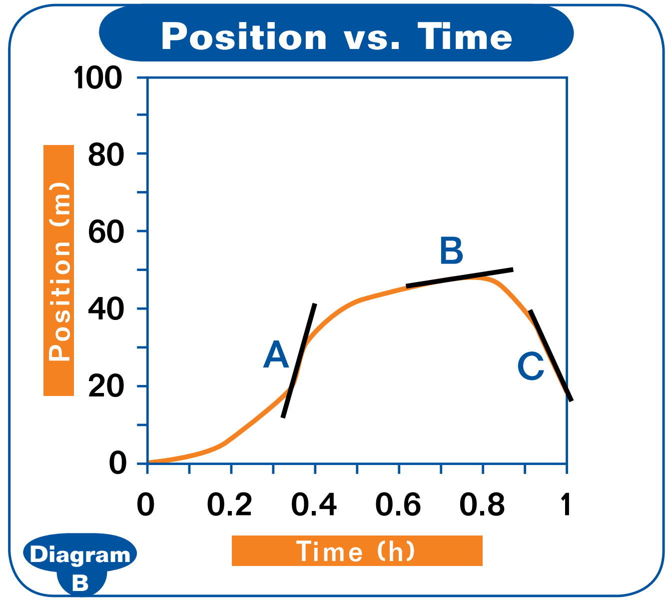


Recall that the velocity is the slope of the position-time graph. So, the object is going fast when the slope is very steep and is going more slowly when the slope is more gradual. (Diagram B)

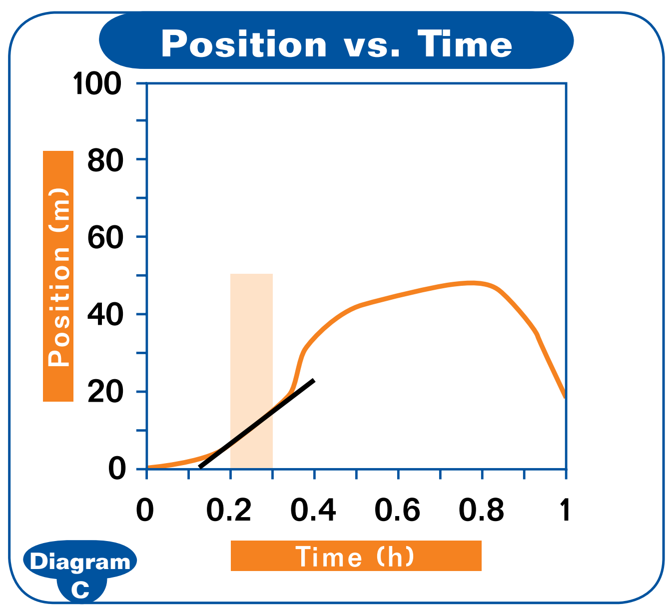
Point A – steep slope, going fast

Point B – gradual slope, going slow

Point C – steep slope, going fast but in the opposite direction.



In most cases we can closely approximate an instantaneous velocity by choosing a small enough interval of time such that the graph is almost a straight line. For example, using the position-time graph, if we choose an interval of time from t = 0.2 h to t = 0.3 h and draw a line between these two points, this straight line closely approximates the curve. (Diagram C)



The average velocity for this interval is:

$$v_{avg} = \frac{\Delta \mathbf{d}}{\Delta t} \qquad v_{avg} = \frac{20 - 10}{0.3 - 0.2}$$

$$v_{avg} = \frac{\mathbf{d_2} - \mathbf{d_1}}{t_2 - t_1} \qquad v_{avg} = +100 \text{ km/h}$$

This average closely approximates the instantaneous velocity at the midpoint of the interval. In this case, the midpoint between t = 0.2 h to t = 0.3 h is 0.25 h. Therefore, the instantaneous velocity at 0.25 h is very nearly 100 km/h. Mathematically, we write $v_{0.25}$ = 100 km/h.

PRACTICE

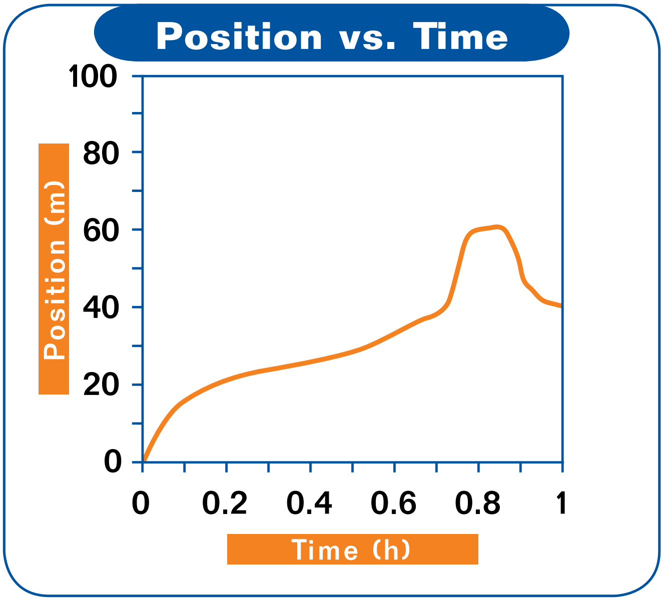
1. Using the position-time graph as your guide, tell a story about an object that might move in this manner.

2. From the graph, calculate the average velocity between the following points and comment whether or not the average velocity closely approximates the instantaneous velocity at the midpoint of the interval.

a) t_1 = 0 h and t_2 = 0.1 h

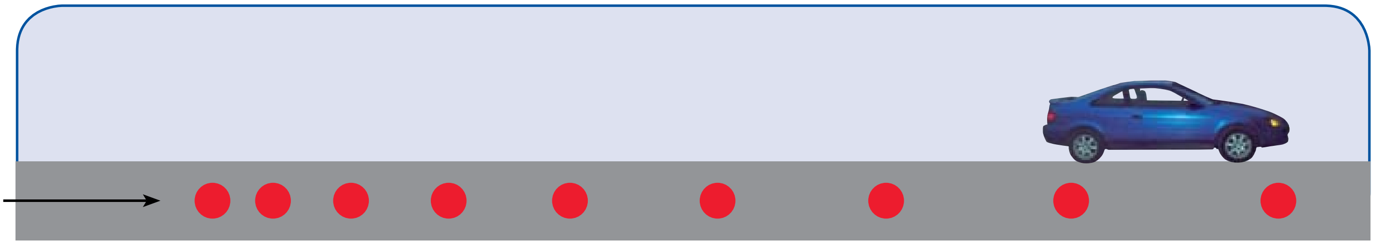
b) t_1 = 0.2 h and t_2 = 0.4 h

c) t_1 = 0.6 h and t_2 = 0.8 h



Accelerated Motion

As you drive your car from a stop light or a parking spot, you must gradually increase your speed from zero to the posted speed limit. When a vehicle speeds up or slows down, we say that it is accelerating.



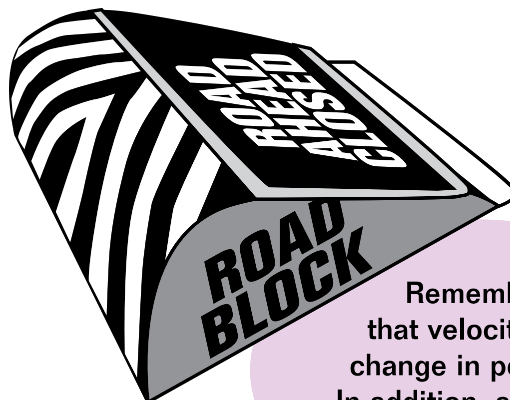
CLASS ACTIVITY:

Remember the dots from the mini-V car as it rolled down the ramp? Did you notice that the spaces were increasing for equal time intervals? As the car moves faster, the distance between the dots increases. Measure the distance between the dots for each interval and complete Table C (you can use your results from page 11 or use the diagram above). Graph your results with the position on the y axis and the time on the x axis.

Table C

Position (cm/s)	Time (s)
	0
	1
	2
	3
	4
	5

It is very easy to mix up the terms velocity and acceleration.



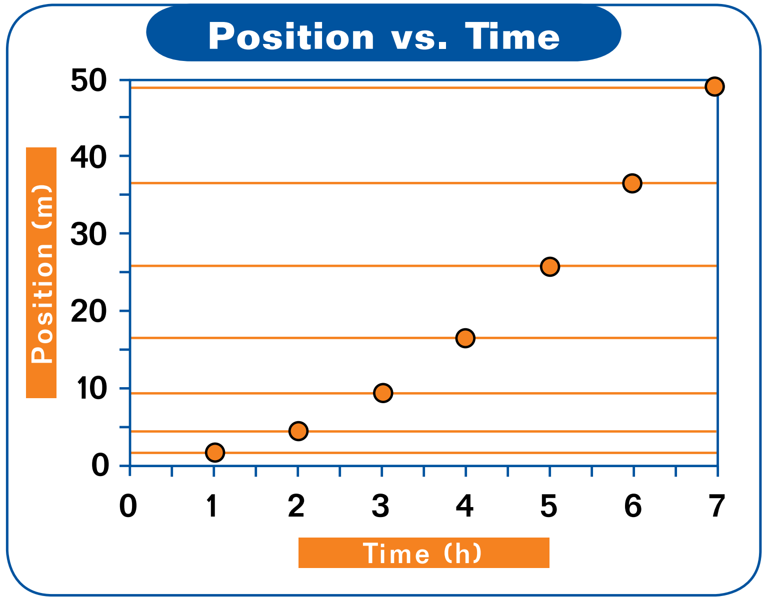
Remember that velocity is a change in position. In addition, an object must change its velocity to accelerate.

Think About IT!

1. Does your graph describe uniform or non-uniform motion?
2. What can you say about the spacing of the dots and the velocity of the car?
3. What can you say about the acceleration of the car?

From your position versus time graph, the line curves upwards because the spacing between the dots is increasing. We can draw reference lines on the graph to show how the points on the curve correspond to the spacing of the dots.

In order to investigate the changes in velocity we must graph the instantaneous velocities for several different times. First, complete Table D to find the average velocity for each interval of time.



In order to find how velocity changes, we must graph instantaneous velocity versus time.

Graphing Instructions

1. First, calculate the average velocity for each interval to complete Table D.
2. Remember that the average velocity of an interval closely approximates the instantaneous velocity at the midpoint of the interval. Use Table D to complete Table E and then graph velocity versus time.

Table D

Time (s)	Position (cm/s)	Average Velocity (cm/s)
0		
1		
2		
3		
4		
5		
6		
7		

Table E

Velocity (cm/s)	Time (s)
	0.5
	1.5
	2.5
	3.5
	4.5
	5.5
	6.5

Think About IT!

1. How does the velocity change in this example?
2. What can you say about the relationship between velocity and time in this case?
3. What do you conclude about the acceleration?

Analysis of Accelerated Motion

Since the velocity changes at a constant rate, the graph of velocity versus time is a straight line. The slope of this line is the rate of change of velocity with respect to time and is called acceleration. Therefore, we can say:

$$\text{Acceleration} = \frac{\text{Change in Velocity}}{\text{Change in time}}$$

or in SYMBOLIC FORM

$$\mathbf{a} = \frac{\Delta \mathbf{v}}{\Delta t}$$

Acceleration is a vector quantity and always has the same direction as the change in velocity.

PRACTICE

1. Table F shows the velocity in m/s of different objects at regular intervals of time. Sketch the velocity-time graph for each case and describe the motion.

Table F

Time	0.0 s	1.0 s	2.0 s	3.0 s	4.0 s
Case 1	0.0	+ 4.0	+ 8.0	+ 12.0	+ 16.0
Case 2	+ 24.0	+ 24.0	+ 24.0	+ 24.0	+ 24.0
Case 3	+ 24.0	+ 16.0	+ 8.0	0.0	-8.0
Case 4	+ 2.0	+ 4.0	+ 6.0	+ 8.0	+ 10.0

2. Compare and contrast uniform and non-uniform motion. Include reference to position, velocity, and acceleration.

3. Find the acceleration in each case.

a) A car increases its velocity from 0 km/h to 20 km/h in 6 seconds.

b) A train crosses a boulevard at 10 km/h and begins accelerating as it heads out of the city. Thirty minutes later it crosses another road at 60 km/h. What is the average acceleration of the train during this period of time?

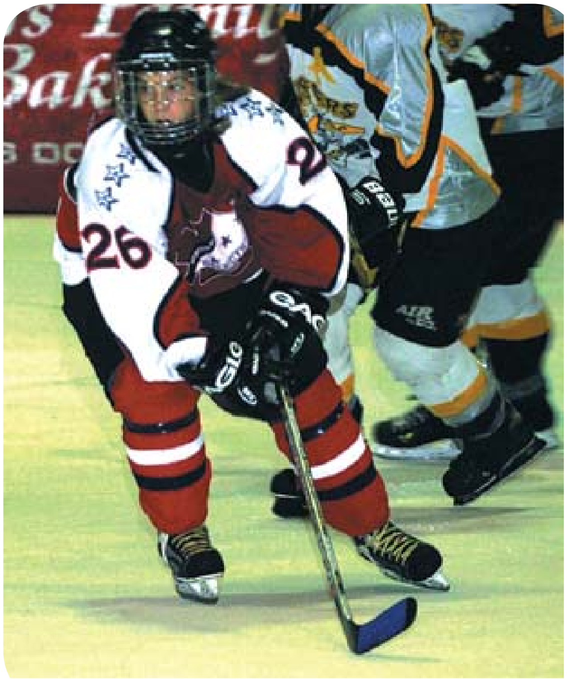
c) A truck travelling west at 50 km/h pulls out to pass another vehicle that is moving at a constant velocity. The truck increases its velocity to 60 km/h in 6 seconds.

d) Estimate your own acceleration when starting from rest to your maximum velocity.

4. In each case from question #3, sketch the corresponding position-time graph. First, choose and label an origin and then choose an appropriate scale.

Real-life Motion

Real-life motion is much more complex than the ideal cases that we have just covered. Other factors, such as friction, must be taken into account when we analyse motion. However, we can still apply some of these basic principles to study motion in the real world. Using a camcorder, record some motion in the real world. You can videotape a car driving down the highway, a cyclist, electric toys moving across tables or over ramps, skaters, or any other type of motion you find interesting. You can even use your favourite action video. However, for the segment that you wish to analyse be sure that the camera does not pan. Place an acetate sheet over the TV screen. Then replay the video frame by frame and mark a dot on the object in motion. When you have a series of dots, analyse them and tell a story about the motion in terms of position, displacement, velocity, acceleration and time.



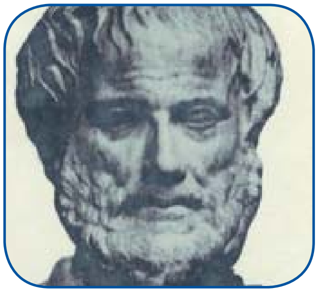
Think About IT!

The following diagram illustrates animal footprints left behind in the snow. Reconstruct what happened from the footprints and your knowledge of motion.

Chapter 3

Inertia

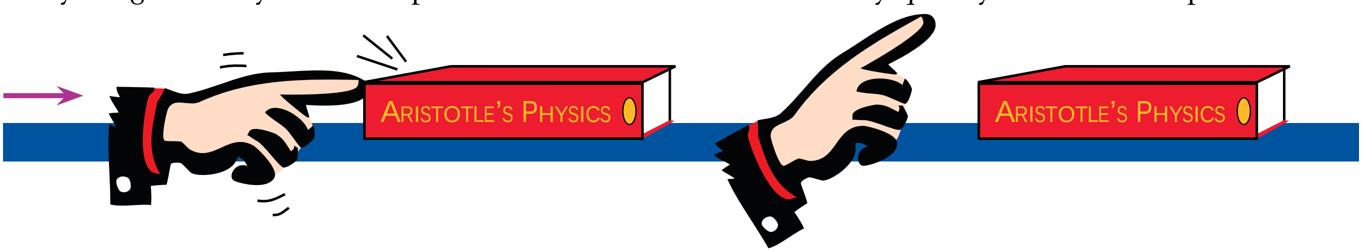
Natural Motion – Aristotle



One of the most fundamental questions about motion that we can ask concerns the natural motion of an object. That is, how would an object behave if it were free of any constraints or forces acting on it? The great Aristotle pondered this question more than 2500 years ago.

Aristotle, a Greek philosopher, offered the first coherent description of the natural world. The first thing he did was separate the celestial and terrestrial worlds into two realms of experience. In the celestial world of the stars and planets, everything naturally moved in perfect circles with a constant velocity. In the terrestrial world, the natural tendency of objects was to move toward the centre of the universe, that is, toward the centre of the earth. Remember, the Greeks believed in a geocentric model of the universe with the earth at its centre.

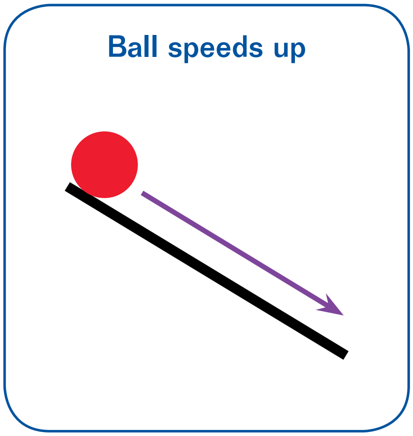
Aristotle's physics adequately explained one of the most basic laws of motion: "what goes up, must come down". According to Aristotle, any motion that was not up or down could only be attained if a force acted on the object. Aristotle called this violent motion. In Aristotle's physics, you must apply a force to move an object and continue to apply this force to keep the object in motion. Try it yourself. Push a book along a table and then remove your hand from the book. The book very quickly comes to a stop.

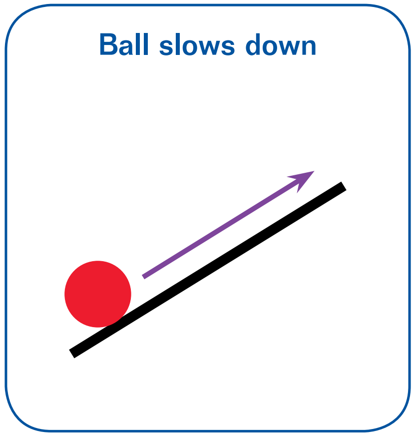


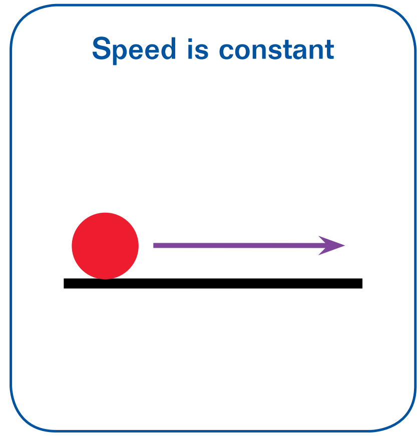
Natural Motion – Galileo

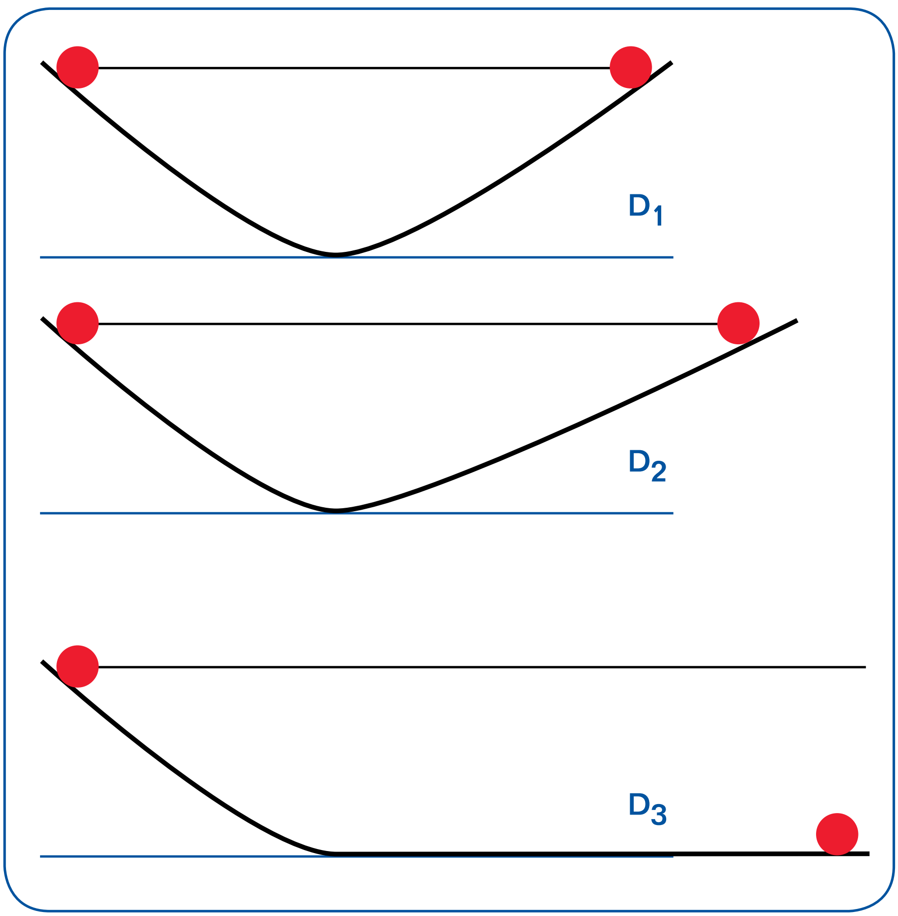
Galileo questioned Aristotle's physics. He knew that motion in the real world was much more complex. The reason the book comes to a stop in the real world is that when you remove your hand there is still friction between the book and the table. That is, another force is acting on the object. One of Galileo's great contributions to science was his ability to think of an "ideal" world without friction. Galileo experimented in his ideal world using thought experiments. He reasoned how the world would behave and then extended these principles to the real world.

For example, Galileo argued that if a ball was released on an inclined plane it would speed up as it rolled down the plane. If a ball was rolled up the plane it would slow down as it moved up the plane. Consequently, Galileo surmised that if the plane were not inclined at all, the ball would neither speed up nor slow down. This meant that the ball would continue its motion with a constant velocity forever.







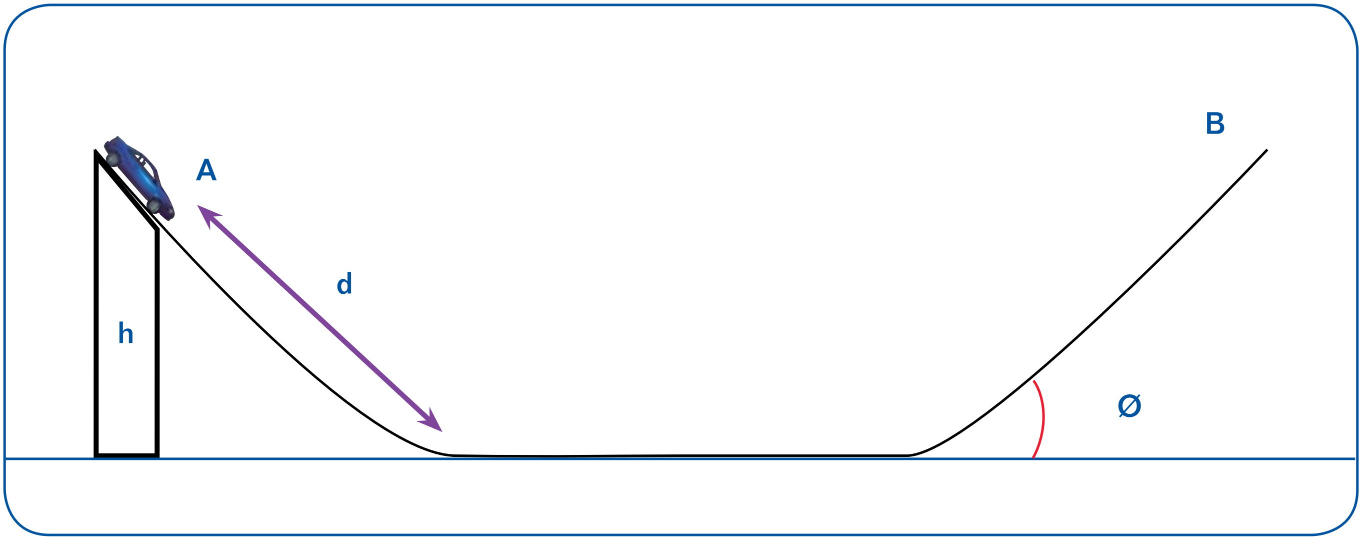


In another thought experiment, Galileo released a sphere down an inclined plane facing another incline. In Galileo's "ideal world", the sphere will rise up the plane on the other side to the same height (D_1). If we decrease the angle of the right plane (D_2), then the mass must travel further in order to achieve the same height from which it is dropped. If we continue to decrease the angle (D_3), it follows that if the second plane has an angle of zero (i.e., horizontal) the sphere will continue forever as it tries to achieve the same height from which it was dropped.

CLASS ACTIVITY:
Galileo's Thought Experiment

We can imitate Galileo's thought experiment using our mini-Vs.

1. Set up a mini-V track as shown and measure the angle of inclination of the ramp (Ø). Choose your best mini-V for this activity.



2. Measure the height from where you release the car at point A and then measure the height the car rises up the other side of the ramp at point B. How do these heights compare?

3. Measure the distance down the ramp and the distance up the ramp. How do these compare?

4. Decrease the angle of the "up" ramp and release the car from the same height. Again, measure and compare the height above ground level and the distance the car moves along the second inclined plane.

Think About IT!

1. **As the angle decreases, what happens to the distance the car travels along the "up" ramp? Why does this distance increase?**
2. **If the angle of inclination is zero, how far would we expect the car to go?**

Remember that Galileo thought about motion in an ideal world. He explained that when you pushed a book across the table and removed your hand, another force, called friction, brought the object to rest. Galileo was a very smart man and thought very carefully about the physics of motion. He knew that the earth was round and what we thought of as a flat piece of the earth was really part of a larger circle. Thus, Galileo concluded that in the absence of any force, an object would continue in motion in a circle around the earth. Although the brilliant Galileo rejected many of Aristotle's ideas, he maintained that the natural motion of an object was circular.

Another great thinker of the time, René Descartes, modified Galileo's idea of natural motion and concluded that the natural tendency of a moving object was really in a straight line.

Although Descartes was the first to propose straight line motion as a natural tendency, it was Isaac Newton who synthesized these ideas about force and motion in his famous book, *Principia*. The property of matter that resists changes in motion is called inertia and is outlined by Newton's First Law of Inertia which states:

An object at rest remains at rest, and an object in motion remains in motion, unless acted upon by an external unbalanced force.

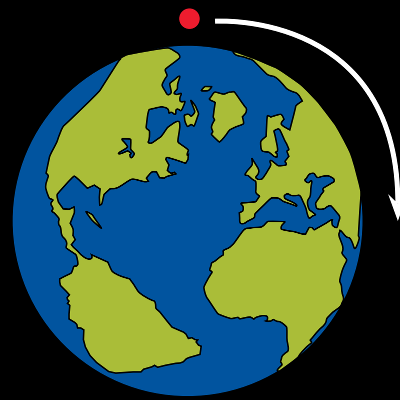


FIGURE 7:
GALILEO'S CIRCULAR INERTIA

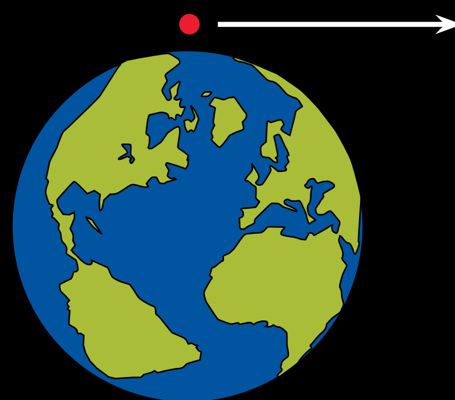


FIGURE 8:
DESCARTES' INERTIA

PRACTICE

1. Make a sketch of the interval spaces for inertial motion.

2. Make up a set of data that reflects inertial motion.

3. Sketch a graph that reflects inertial motion.

4. What is meant by an unbalanced force?

5. What was missing in Aristotle's analysis of natural motion?

6. What was missing in Galileo's analysis of natural motion?

Newton's First Law and the "Second Collision"

Newton's laws apply to all moving objects (and those that don't move, too). Motor vehicles are moving objects that **always** obey the law – Newton's law, that is! According to Newton's first law, a motor vehicle in motion will remain in motion, moving at the same speed and direction, unless acted upon by an unbalanced force. The same principle applies to all occupants and objects in the vehicle. When a moving vehicle suddenly stops in a collision, any unrestrained occupants in the car will continue to move with the same speed and in the same direction until they experience another force. This force is often called the "second collision". Although we say the occupants have been "thrown" from the vehicle, they are really just continuing to move with the same inertia until they experience an unbalanced force in another collision. In the next investigation, we will research some of the factors that might influence how far an unrestrained occupant will be "thrown" from a vehicle. First, we must learn how to control the speed of our mini-Vs.

The Velocity of a Car on an Inclined Plane

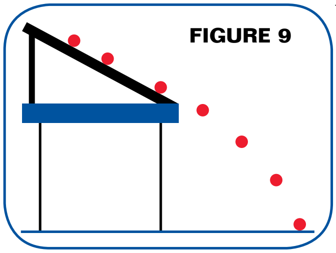
For the following exercises, it is necessary to control the velocity of the mini-V car on an inclined plane. Since the car accelerates down the plane we must determine where to release the car on the plane in order to increase the velocity at a known rate. There are several ways that this may be approached. Two examples are described here: calibrating the inclined plane and historical reasoning.

Calibrating the Inclined Plane

Set up a ramp at the edge of a table and carefully measure the angle of inclination (Figure 9). The end of the ramp should bend slightly so that is matches the horizontal surface of the table.

If we release a ball from some point on the ramp, it accelerates down the ramp to velocity v1 and then is horizontally projected into the air with this velocity. Once the ball leaves the inclined plane, gravity accelerates the ball in the vertical direction. There are no forces acting on the ball in the horizontal direction (ignoring air resistance).

FIGURE 9



Consequently, the ball moves away from the table with a constant velocity.

We can confirm this type of projectile motion by recording the motion using a camcorder. If you play back the motion frame by frame and measure the horizontal displacement of the projectile, you will find that it is constant. We know that:

$$\mathbf{v} = \frac{\Delta \mathbf{d}}{\Delta t}$$

therefore

$$\Delta \mathbf{d} = \mathbf{v}\Delta t$$

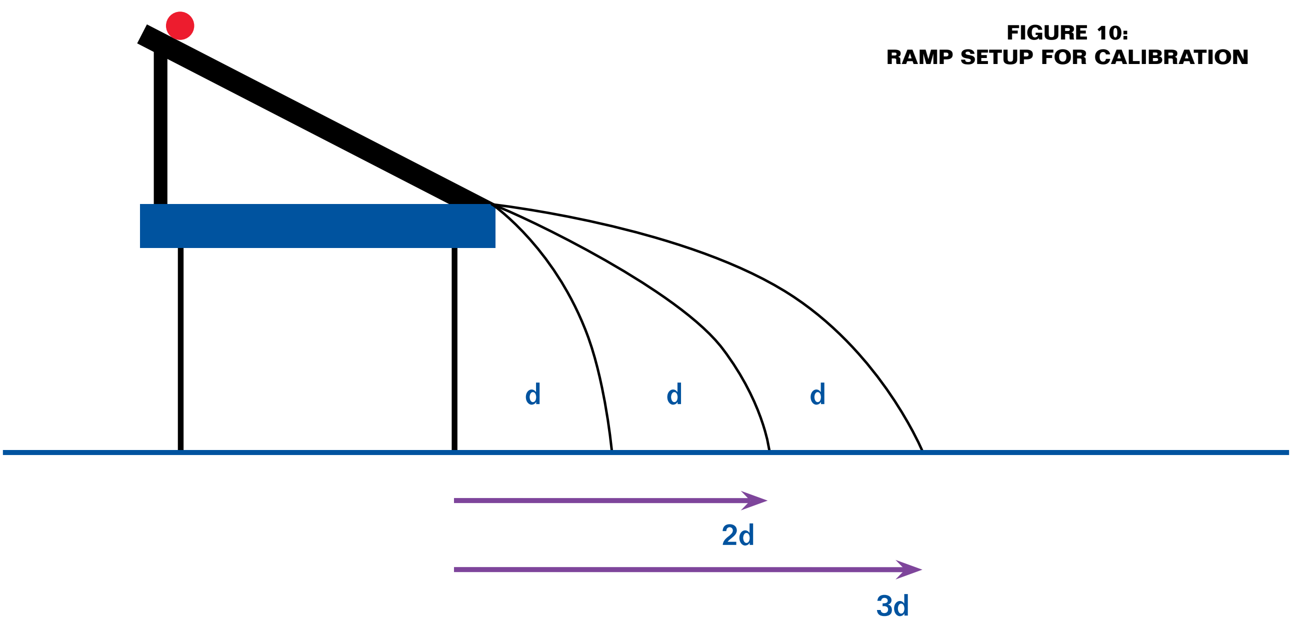
That is, the distance the ball travels horizontally is proportional to the velocity of the ball when it leaves the ramp. Consequently, if we find the release points on the inclined plane such that the successive horizontal displacements are always equal, we will also know that the velocities increase at a constant rate.

Procedure to Calibrate the Inclined Plane

The distance "d" is not critical and will depend on the ramp angle and height of the table. Choose "d" such that you can get at least five or six velocities from your ramp. A typical distance is 12 - 15 cm. In the following example, d = 12 cm (Figure 10).

In order to preserve your mini-Vs, find a marble that travels the same distance as the mini-V car when it is released from the midpoint of the plane.

FIGURE 10:
RAMP SETUP FOR CALIBRATION



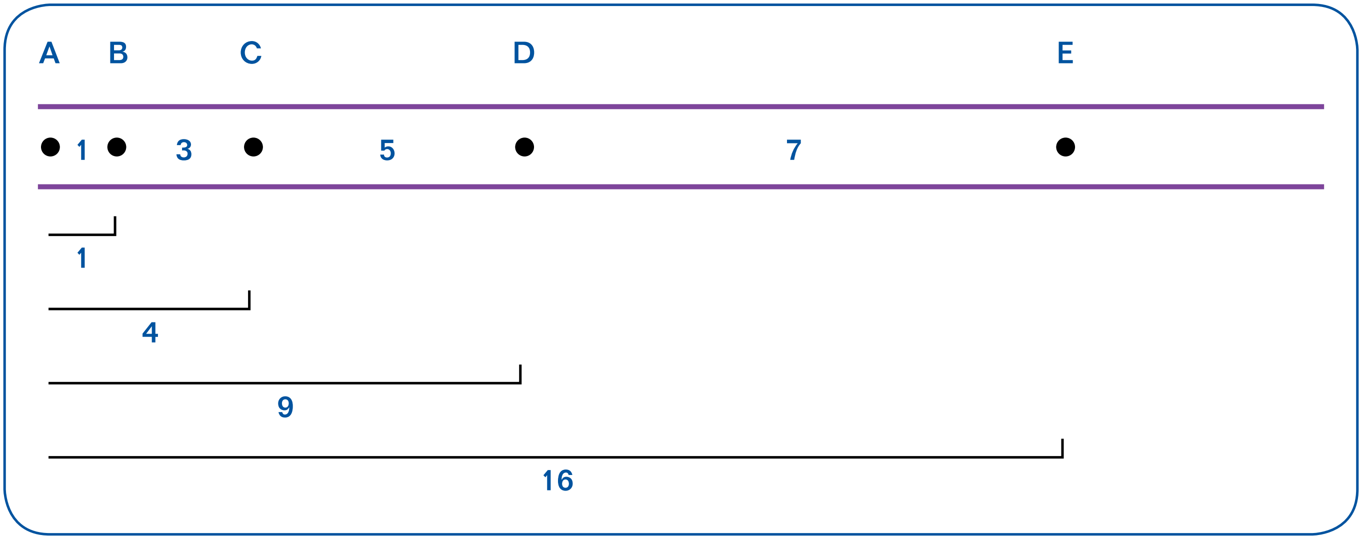
1. Place a narrow object (a pencil works fine) on the floor at a distance 12 cm from the edge of the table (1d) and find the release point on the inclined plane so that the marble lands on this object. Let's say that a ball released from this point has a velocity of v = 1 (arbitrary units). Mark the release point on the ramp with a piece of masking tape.

2. Next, place the pencil at 2d (if d = 12 cm, then 2d = 24 cm) and repeat the procedure. A marble that lands at 2d will have velocity of 2v.

3. Repeat for 3d, 4d and 5d (if d = 12 cm, then 36, 48 and 60 cm). Your ramp is now calibrated. Do not change the angle of the ramp when you begin your investigation. If you change the angle of the ramp, you must recalibrate.

Historical Reasoning

Galileo showed that an object that is accelerating (either in free fall or down an inclined plane) covers a displacement according to the odd numbers (1, 3, 5, 7, etc.) for equal time intervals. In other words, Galileo's ticker tape, if he had one, would look like this:



Since the object is accelerating at a constant rate (due to gravity), the velocity must increase proportionally for these intervals. That is, the velocity at C is twice the velocity at B, and the velocity at D is three times the velocity at B, and so on. Since the distance from the origin follows the pattern 1, 4, 9, 16 (add up the individual displacements), if we release a car from these positions on an inclined plane, we will know that the velocity also increases proportionally. In order to get a greater variation in velocity, we can multiply this pattern by a constant value. A convenient scale for our experiment would start at 5 cm. Table H lists the release points for a typical inclined plane.

Table H

Ratio needed	Scale Factor	Release Point (cm)	Relative Velocity
1	x 5	5	1
4	x 5	20	2
9	x 5	45	3
16	x 5	80	4
25	x 5	125	5

Think About IT!

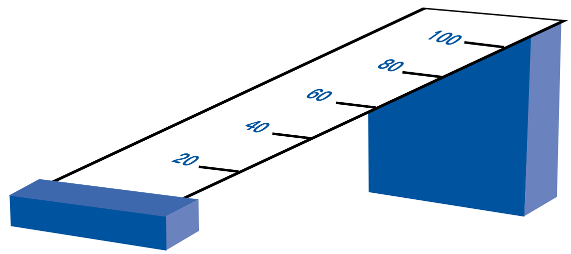
1. How do your calibration ratios compare to Galileo's ratio pattern of 1, 4, 9, 16, 25? (To find your ratio pattern, divide each release point by the first value.)
2. What is the mathematical significance of the pattern 1, 4, 9, 16, 25?

Inertia and Unrestrained Occupants

In a car crash, it is not unusual for the unrestrained occupants to be "thrown" from the vehicle. According to the laws of physics, after the vehicles collide (coming to an abrupt stop), the occupants' inertia will carry them until some external force brings them to a halt. (Remember, an object in motion stays in motion unless acted upon by an unbalanced force.) Inevitably, the external force is the ground, a tree, a building, or some other immovable object. In other words, in every collision there are always two collisions: the vehicles' collision, and the occupants' collision.

Investigation #2 INERTIA AND THE UNRESTRAINED OCCUPANT

In this activity, you will investigate the relationship between the distance an unrestrained occupant travels in a collision and the speed of the vehicle.



Procedure

1. Set up an inclined plane and secure a barrier at the bottom of the plane. Mark the points on the plane from where you will release your car (see previous discussion: calibrating an inclined plane).

2. Make yourself an "occupant" using plasticine and rest your occupant on the hood of a mini-V car.

3. Release your car down the plane such that the velocity increases at regular intervals, and record the distance the occupant is "thrown" after the collision with the barrier.

4. After three trials, calculate the average distance.

Speed	Trial #1	Trial #2	Trial #3	Average distance the occupant is "thrown" (cm)	Comments
1					
2					
3					
4					
5					
6					

Think About IT!

1. Graph the average distance the occupant was thrown versus the speed of the car.
2. What does your graph tell you about the relationship between the distance an unrestrained object is "thrown" and the speed of the vehicle?
3. What are some of the factors (besides speed) that affect the distance the occupant is thrown from trial to trial?

Challenge

Devise an experiment to "idealize" the Inertia and Unrestrained Occupant activity. You will need a device to propel an object at different velocities that increase evenly, and an object that comes to rest in a regular manner.

Summary

The relationship between the distance an unrestrained occupant is "thrown" and the velocity of the car is called an exponential relationship. These types of relationships are common in the ideal world described by our physics equations. In the real world, an exponential relationship means that as one variable increases, the other increases at a faster rate. That is, if you double the speed of a car in a collision, the distance an occupant can be "thrown" increases by more than double. In other words, speed kills.

In our real world experiment, the distance that the occupant is "thrown" varies from trial to trial. The size and symmetry of the occupant, his/her limbs, the angle at which the occupant contacts the ground, and skid all affect where the occupant lands. In an idealized experiment, if you double the speed of a car in a collision, the distance a occupant can be "thrown" increases by a factor of four!

Think About IT!

1. What is the "ideal" relationship between the distance an unrestrained object is "thrown" and the speed of the object?

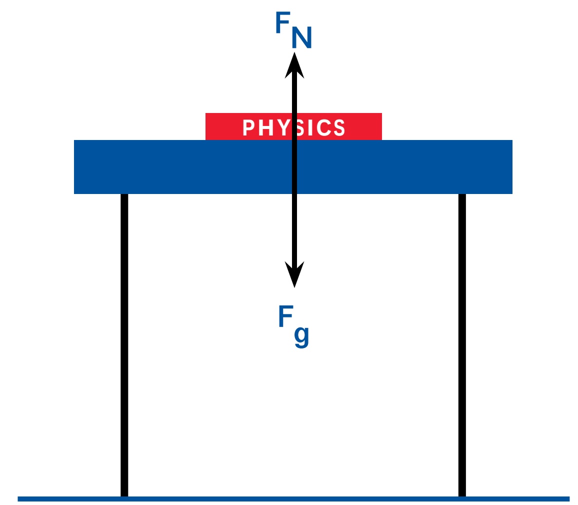
Speed Kills

It is often tempting to drive above the speed limit. However, the laws of physics suggest that assessing the risks associated with speeding are worth consideration. History also proves our point. In the 1970s during the oil crisis, the United States government reduced speed limits to conserve fuel. The number of crashes and deaths were also reduced substantially.

Chapter 4

Forces and Motion

We know from Newton's First Law of Inertia that an object at rest remains at rest and an object in motion remains in motion unless acted upon by an external unbalanced force. A force is unbalanced when it is not cancelled by another force. For example, if a book rests on a table, the force of gravity pulls the book down but the book does not move. Another force, the force of the table pushing up (called the normal force, F_N), balances the force of gravity. If we remove the table, the force of gravity is no longer balanced by the normal force and the book falls to the ground.



There are lots of different ways to exert an unbalanced force on an object. We could push it, pull it with a string or rope, or use gravity, electrical or magnetic forces. Even the force of friction can be an unbalanced force when no other forces are acting on the object.

Atwood's Machine

In 1784, George Atwood published one of the first textbooks on Newtonian mechanics. The textbook, titled *A Treatise on the Rectilinear Motion*, included a device, now known as Atwood's machine, to investigate Newton's laws. Two different masses were suspended over a pulley by a light cord. The pulley turned with a very low friction and the acceleration of the system of masses was measured. We will use a slightly different pulley system, based on Atwood's ideas, to demonstrate the relationships between force, mass and acceleration for a dynamics cart.

Think About IT!

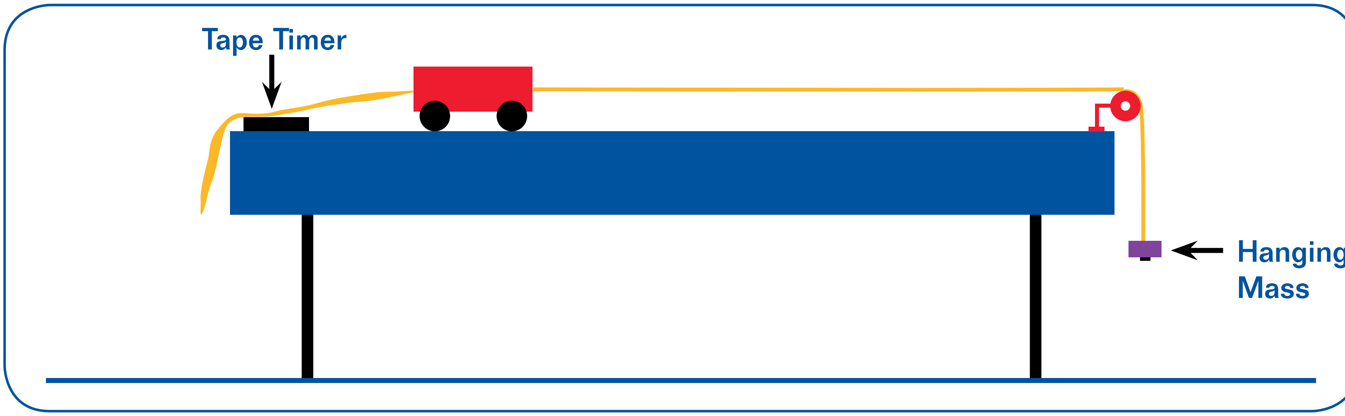
1. A car accelerates from a stoplight, slows down and turns left into a driveway, and then brakes to stop. Summarize the forces that are acting on the car.
2. Draw a diagram to show the forces on the car in question #1. Each time the forces change, draw a new diagram.

Investigation #3 FORCE AND ACCELERATION

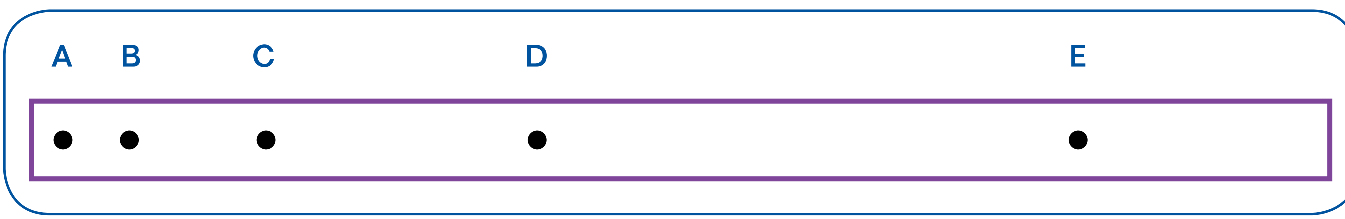
Newton's first law tells us how an object behaves when it is at rest or in motion with no unbalanced forces acting on it. What happens if an unbalanced force acts on an object?

Procedure

1. Set up the following apparatus using a tape timer, a dynamics cart (or similar), and a pulley and mass system.



2. To measure the motion of the cart, use a method similar to Chapter 2. Start the tape timer (you could also use a motion detector or a video recorder) at the same time that you release the falling mass. The force of gravity acting on the mass pulls the cart with a constant force. Examine the spacing of the dots on the ticker tape. A typical dot pattern looks like this:



Think About IT!

1. From the tape and the spacing of the dots, what can you conclude about the relationship between a constant force and motion?

Math Connection

We can more accurately investigate the changes in velocity by graphing instantaneous velocity versus time. Repeat the procedure from Chapter 2 by copying and completing Tables C, D and E from pp. 18 - 20 and the graph of velocity versus time. Remember that the average velocity of an interval closely approximates the instantaneous velocity at the midpoint of the interval. From the graph of velocity versus time, what can you conclude about the relationship between a constant force and the motion?

Summary

We can tell by the spacing of the dots that a constant force causes the cart to accelerate. If we analyse the motion and graph velocity versus time, we find that the line is straight, meaning that the acceleration is constant. That is, a constant force causes constant acceleration.
So far, we have found that:

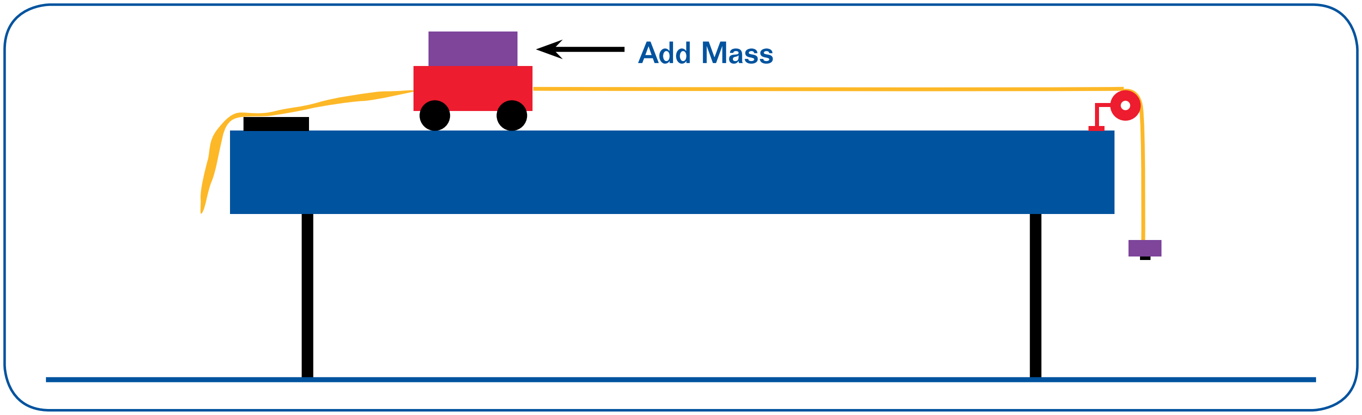
- When the force on an object is zero, the acceleration of the object is also zero (inertia),
- When we apply a constant force to an object, the acceleration of the object will also be constant.

Think About IT!

1. **Make and compare 2 concept maps on force and motion. The first concept map uses the central idea, "forces are balanced", and the second uses "forces are unbalanced".**

Investigation #4 MASS AND ACCELERATION

To find the relationship between mass and acceleration, we can repeat the experiment using a larger dynamics cart. Increase the mass of your dynamics cart each time and repeat the procedure of Investigation #3 to find the acceleration for each case.



Think About IT!

1. **From the data, what do you conclude about the relationship between mass and acceleration?**

Math Connection

We can more accurately investigate the relationship by graphing mass versus acceleration. Describe the curve on the graph of mass versus acceleration. From the graph, what do you conclude about the relationship between mass and acceleration?

Investigation #5 FORCE AND MASS

To find a relationship between force and mass, we can repeat the experiment again using another dynamics cart. Double the mass of your dynamics cart and experiment to find the force that produces exactly the same acceleration as the first case.

Think About IT!

1. **From the data, what do you conclude about the relationship between force and mass?**

Summary

We know from our own experiences that if we increase the mass of an object, it becomes more difficult to accelerate. A mass is like a resistance to motion. Therefore, it takes more force to accelerate a larger mass. By carefully examining many different cases, we know that if we double the mass we must double the force in order to produce the same acceleration. In mathematical terms, force is proportional to mass.

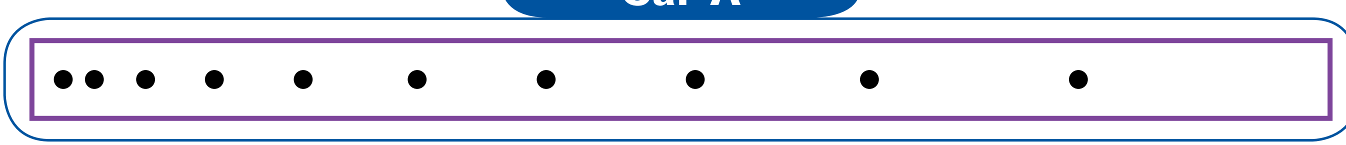
We also know from our own experiences that when we push heavier objects, the objects accelerate more slowly. If we collect several examples and graph mass versus acceleration (when a constant force acts on an object), the graph is an inverse curve. A curve of this type means that as the mass increases, the acceleration decreases at exactly the same rate. In this case, our experiences and the mathematical analysis tell us the same thing.

Force and acceleration are important principles to understand before you drive a car. Cars constantly stop and start their motion, especially in traffic. If we apply large forces, we accelerate rapidly. Remember the dot spacing! This means that for equal intervals of time, the car will cover a larger distance, making it more difficult to react to changes on the road in front of you. Young children often have difficulty judging such distances, making it imperative that the driver accelerate such that the speed of the car increases at a controlled pace.

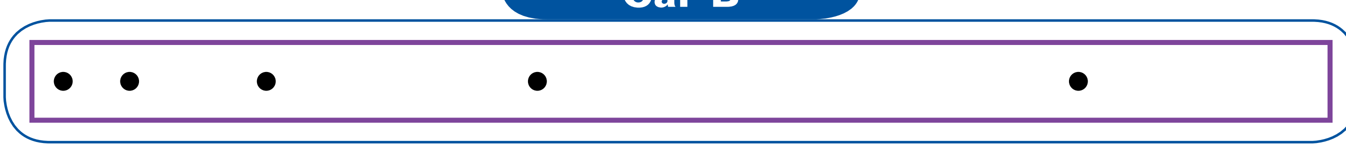
Think About IT!

1. **The following tapes illustrate the interval spacing for two cars accelerating from a stoplight. Some distance down the road, where children are playing, a ball rolls onto the road. Write a paragraph to explain the situation to a new driver in terms of force and motion.**

Car A



Car B



Force and Direction

So far we have considered objects that accelerate by changing their speed in a straight line only. Consider what takes place when a car enters a curve in the road. What happens if the road is slippery (like after a rain) or if the speed of the car is too great as it enters the curve?

Remember Newton's First Law of Inertia? A car in motion will stay in motion unless acted upon by an unbalanced force. In this case, unless there is a force to change the direction of the car, then the car continues in a straight line into the ditch. That is, a force is needed to change the direction of motion.

Physicists refer to any change in motion, including directional changes, as acceleration. For a car negotiating a curve, the external force comes from the friction between the tires and the road. If this force is reduced, then little or no change in direction will occur. For this reason, on an icy day it is not unusual to find a number of cars in the ditch near a curve in the road.

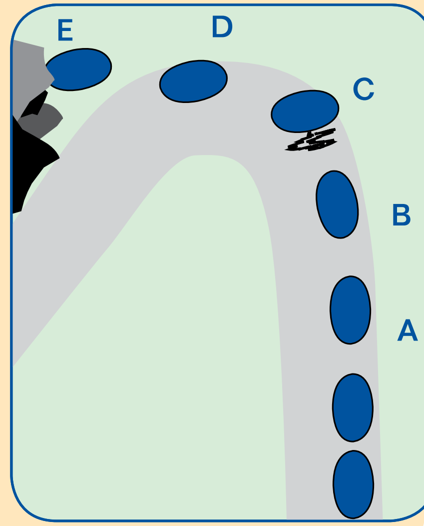
Cornering

Forces are required to change the direction of motion. In order to maximize and properly balance the cornering forces, cyclists must "lean" when they make a turn. If the cyclist doesn't lean correctly he could topple over or the wheels of the motorcycle could slide out from under him or her. Experience and practice are important to safely learn how to corner a two-wheeled vehicle. In Manitoba, motorcycle instructional courses are mandatory and offered by experienced motorcyclists.

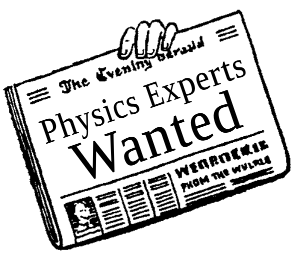
Think About IT!

1. Make a table or concept map linking the main ideas for position, velocity, acceleration, force, direction, and "changes in".
2. Why is a racetrack banked around the corners?
3. A car accelerates rapidly from rest to point B. At point B the driver removes his foot from the gas pedal and enters a curve. At point C, the car encounters "black ice" on the road and the rear wheels of the car skid outside of the radius of curvature of the road. At point D the car continues in a straight line into the ditch at point E, where the car slams into the bank and stops. The windshield is cracked.

   Analyse this scenario in terms of Newton's laws of motion.



4. Why does a water skier (or a hockey player) lean in order to turn?



In the opening chapter of this book, a car crash scenario was described. As a physics expert, review the scenario and write a report to the police describing the motions before and after the collision. Who is telling the truth, the motorcyclist or the car's driver?

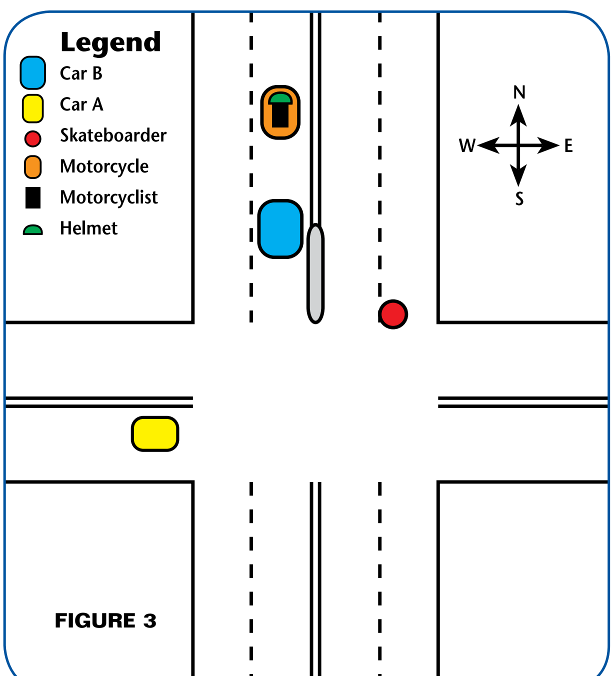


FIGURE 3

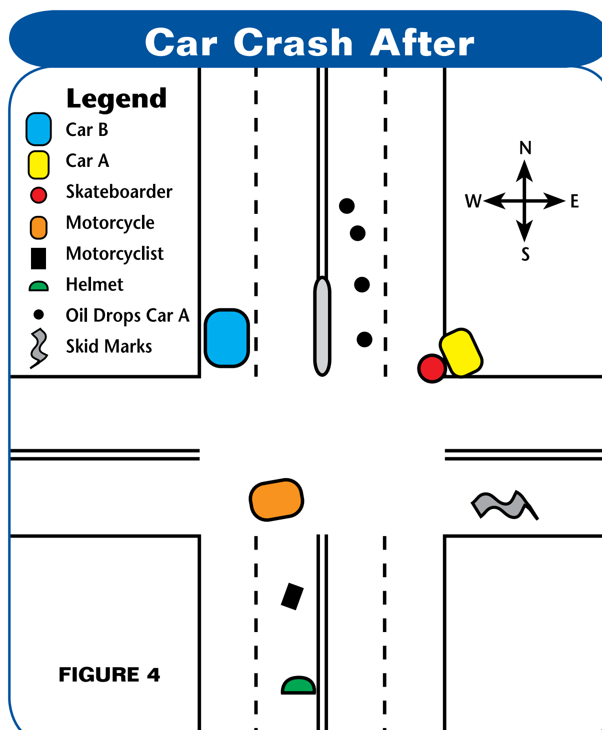
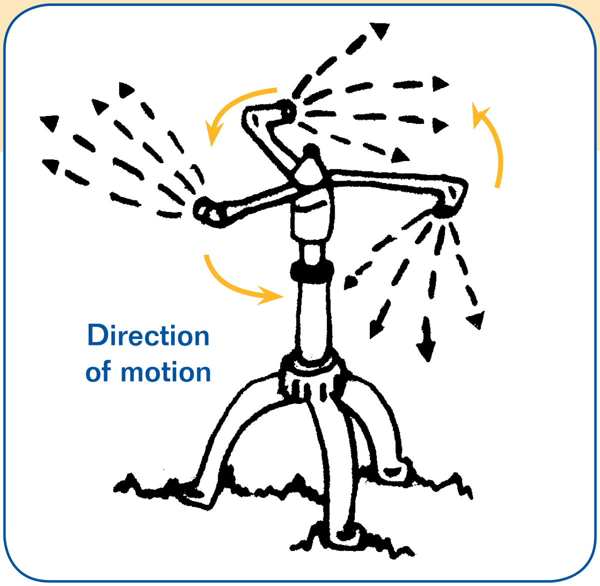


FIGURE 4

Action-Reaction Forces

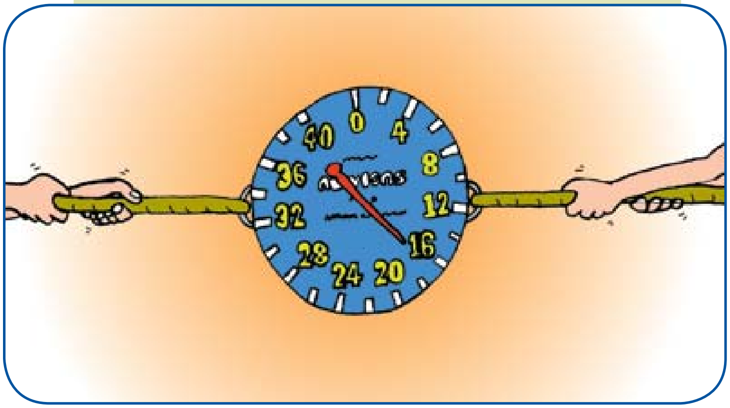
Think About IT!

What makes the sprinkler head turn?



Try IT!

Two students of different masses pull on two pieces of rope that are connected by a spring scale to measure force. What does the scale read? How do we know that the force exerted by the small student is exactly the same as the force exerted by the heavier student?



All forces arise from interactions. Common forces, like the attraction of gravity and the attraction and repulsion of electric and magnetic forces, always occur in pairs. Whenever two objects interact with each other, they exert these types of forces on each other. We call these force pairs or action-reaction forces. Newton summarized these interactions in his third law:

"For every action, there is an equal and opposite reaction."

In all cases, the magnitudes of the forces are equal and the forces act in opposite directions. Consider a book resting on a table. The force of gravity acts downward and the table pushes back with an equal and opposite force. If you're not convinced, try removing the table. Remember the relationship between force and acceleration. Unbalanced forces cause acceleration. Since the force of gravity and the force exerted on the book by the table are balanced, the book resting on a table does not accelerate. If you remove the table, there is no force to balance gravity and the book accelerates downwards.

Think About IT!

1. In each of the following cases, sketch the situation and label the action-reaction pairs.
   a) A person leans against the wall.
   b) A car rounds a corner with a constant velocity.
   c) A fish swims.
   d) A skateboarder jumps.
   e) A gun recoils.
   f) A hockey player takes a slapshot.
2. While driving down the road, a mosquito collides with the windshield of your car. Which of the two forces is greater: the force that the mosquito exerts on the windshield, or the force that the windshield exerts on the mosquito?
3. Two students are facing each other while standing on their skateboards. One student throws a mass (such as a medicine ball) to the other student. Describe what happens in terms of force and motion.
4. In terms of action-reaction force pairs, explain why it is important to use helmets, elbow pads, knee pads, and other protective clothing when using skateboards or in-line skates.

Design Challenge: The "Rocket" Car Race

Use the principles of Newton's Third Law to build and race a rocket car. The car that goes the furthest is the winner.

Suggestions for propulsion – a balloon, a straw, a slingshot design, a mousetrap.

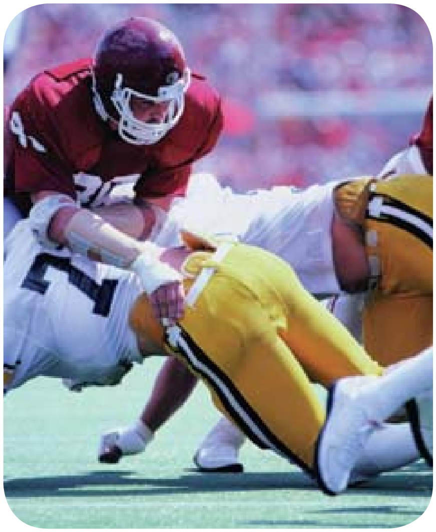
Suggestions for wheels – CDs, pop bottle tops, styrofoam cups (cut to fit), spools.

Suggestions for the frame – cardboard, styrofoam plates.

Chapter 5

Momentum and Energy

Momentum



In everyday life, we often use the word momentum to describe a sports team or a political party that is "on a roll" and is going to be difficult to stop. The common usage of the term momentum has roots in the physics world. Any object that is moving has momentum, and in order to bring the object to rest we must change this momentum to zero.

What makes an object difficult to bring to rest? Would you rather collide with a train moving at 2 m/s or a mosquito moving at the same speed? The answer is obvious: the train can crush a car. However, in the second case, the pesky mosquito never even dents your windshield.

Momentum is a term we use in physics to describe a quantity of motion. If an object is in motion then it has momentum. What are the characteristics of momentum?

Well, from our train and mosquito example, we know that the mass of the train makes it more difficult to stop than a mosquito moving at the same speed. This should make sense if you recall from our discussion of Newton's laws that mass is a resistance to acceleration. Certainly, more mass means more resistance to acceleration, and the more difficult it is to bring the object to rest. However, momentum is not the same as mass. A massive boulder resting on the side of the road has no momentum at all – it is already at rest!

Objects that are moving fast are also hard to stop. Bullets have a very small mass but it can be extremely difficult to try and stop one! If we wish to bring an object in motion to rest, we must take into account its velocity as well as its mass. Newton called this the principle of momentum. Simply stated, if a moving object has more mass, it has more momentum, and if an object has more velocity, it has more momentum. That is, if either the mass or velocity (or both) of an object increases, the object will be more difficult to bring to rest.

Think About IT!

1. In the table below, try to order the following objects according to their momentum. Comment on the reasoning for your choices.

   Transit bus, football, sprinter, statue, race car, marathon runner, slapshot, building, skateboarder

Object	Amount of Momentum (describe in your own words)	Comments

Math Connection

Since the momentum of an object is directly proportional to both its mass and its velocity, we can easily write this as a mathematical relationship.

Momentum = (mass)(velocity)

or in SYMBOLIC FORM $\mathbf{P} = m\mathbf{v}$

(Why do you suppose physicists use the symbol P to represent momentum?)

Momentum is a vector quantity. Its direction is always the same as the direction of the objects' velocity.

We can compare the momentum of the objects in the table by multiplying their mass by their velocity. In the following table, the mass of each object is given. Estimate the velocity of the objects in km/h and calculate their momentum. Compare the calculated results to your order in the previous table.

Object	Mass (kg)	Velocity (km/h)	Momentum (kg-km/h)	Comments
Transit bus	**8 000**			
Football pass	**0.5**			
Sprinter	**75**			
Golden Boy statue	**1 650**			
NASCAR Stock Car	**1 545**			
Marathon runner	**65**			
Slapshot	**0.15**			
Building	**1 000 000**			
Skateboarder	**68**			

Sample Only. Do not write here.

Impulse and Momentum

In order to change motion we need to apply a force. If we continue to apply a force for a long period of time, the object will continue to accelerate, increasing (or decreasing) its velocity more and more. Since we defined momentum as mv, then as the velocity of the object increases, so does its momentum. Therefore, in order to find a change in momentum, we must also know for how much time a force is applied. We call the amount of force and the time during which the force is applied the impulse. If we have more force, we have more impulse. Additionally, if we apply the force for a longer period of time, we also have more impulse. In this way, impulse is proportional to force and time. Consequently, we can define impulse as the product of force and time.

Impulse = (force) (time)

or in SYMBOLIC FORM

$$\mathbf{I} = \mathbf{F} \times t$$

Impulse is also a vector quantity. It has the same direction as the applied force.

The fact that impulse depends on both force and time means that there is more than one way to apply a large impulse to an object – you can apply a very large force for some time, or apply a smaller force for a very long time (or both!).

If an unbalanced force acts on an object it will always cause the object to accelerate. The object either speeds up or slows down. If the force acts opposite to the object's motion, the object slows down. If a force acts in the same direction as the object's motion, then the object speeds up.

Thus, when the velocity of the object is changed, the momentum of the object is also changed. When something exerts a force on you, it also exerts an impulse on you. Forces and impulses always go together. Very simply stated, impulse changes momentum. This relationship is very closely related to Newton's Second Law.

Using the Impulse-Momentum Relationship

If you play sports, your coach has been teaching you about impulse and momentum for many years. In most sports we wish to change the velocity of an object for many different purposes. Hitting a home run, "bumping" on the volleyball court, deflecting a shot on goal, driving a golf ball, or serving on the tennis court require that we change the velocity (and therefore the momentum) of the ball or puck by applying an impulse. In order to improve your performance, the coach might first suggest that you hit the ball harder by building up strength. Increasing your fitness enables you to apply a larger force. Later, your coach will constantly remind you about "following through" in your technique. By developing sound technique, as you follow through, you can increase the amount of time the force acts on the object. Sometimes we want small forces applied on objects, and other times we want large forces. However, if you try to apply too much force you can lose control and your timing is less accurate.

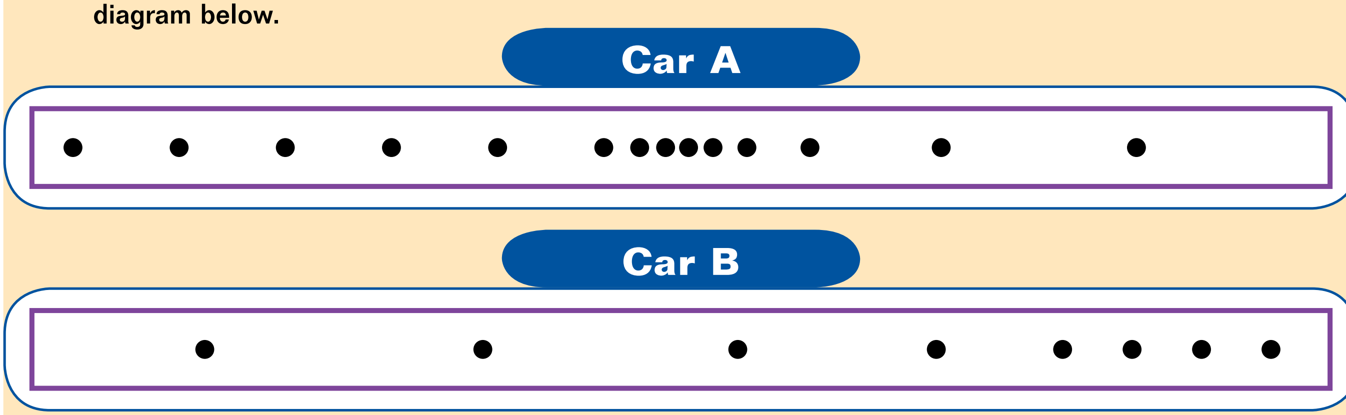
Think About IT!

1. Impulse depends on both force and time. Give an example for each case:
   a) a large force for a short time
   b) a small force for a long time
   c) a large force for a long time
   d) a small force for a short time

2. Analyse each of the following situations in terms of impulse and momentum changes. Discuss possible ways to improve performance.

   a) A professional golfer needs a larger impulse on his drives and a much smaller impulse for his putting.
   b) A gymnast performs a reverse somersault as he dismounts from the high bar.
   c) A volleyball player “sets up” a spike shot.
   d) A baseball player hits a grand slam.
   e) A car brakes for a yellow light.
   f) A bat catcher catches a fastball.

3. Two cars of equal mass are driving down Portage Avenue with equal velocities. They both come to a stop over different lengths of time. The ticker tape patterns for each car are shown on the diagram below.



   a) At what approximate location on the diagram (in terms of dots) does each car begin to experience an impulse?
   b) Which car (A or B) experiences the greatest change in momentum? Explain.
   c) Which car (A or B) experiences the greatest impulse? Explain.
   d) Which car (A or B) experiences more than one impulse?

4. A halfback in a football game (m = 60 kg) runs across the field at 3.2 m/s. An opposing lineman (m = 120 kg) is running toward him at 1.8 m/s. What is the result of their head-on collision?

5. If both the boulder and the boy have the same momentum, will the boulder crush the boy? Explain using the principles of impulse and momentum.

6. It is said that a fool and his money are soon parted. Suppose we place the fool and a gold brick in the middle of a frictionless, frozen lake (Galileo’s ideal frozen lake). How can the fool rescue himself? Is he still a fool?

7. How can a spacecraft change direction when it is in deep space?

Cushioning the Blow

The impulse-momentum relationship is extremely important for understanding how to protect yourself and your occupants from personal injury in a car collision. A 2 000-kg car moving at 50 km/h has a tremendous amount of momentum. In order to stop the car, the car's momentum must be reduced to zero. The only way to do this is to apply an impulse opposite to the car's motion. To safely brake the vehicle, we apply an impulse by exerting a force on the wheels for a long period of time. In cases where the car stops rapidly, as in a collision, the impulse is applied over a short duration of time, resulting in very large, destructive forces acting on the car and its occupants. In order to cushion the blow, manufacturers have invented several devices that use the impulse-momentum relationship by increasing the amount of time for the impulse and, consequently, decreasing the applied force.

It's kind of like an egg toss. If you catch the egg without allowing your hands to "give", then the force is usually too large for the egg and the egg breaks.

Challenge

Can you and your classmates design another activity to demonstrate the cushioning effect of the impulse-momentum relationship?

Try IT!

Two students hold a large blanket upright. Another student throws an egg into the blanket.

You should curl the bottom of the blanket so that the egg doesn't drop on the floor.

Be sure to throw it hard.

Cushioning Devices

Bumpers

Bumpers are designed to minimize the damage to a vehicle in a collision by absorbing some of the impulse. Today, cars use bumpers that have the ability to compress because of their material and/or through the use of a special kind of bumper mechanism.

Crumple Zones

A crumple zone is a part of a car that is designed to compress during an accident to absorb the impulse from an impact. A crumple zone increases the amount of time it takes the car to stop, and therefore decreases the amount of force in the impulse. Crumple zones mean that the impulse is reduced before it is passed on to the occupant compartment.

Padded Dashboards

If a driver or occupant hits the dashboard in a collision, then the force and time required to stop their momentum is exerted by the dashboard. Padded dashboards increase the duration of the impact, minimizing the amount of the force of the impulse.

Think About IT!

Why are the bumpers on cars today much more absorbent than cars fifty years ago?

Try IT!

A crumple zone behaves much like a pop can crusher.

Seat Belts

According to the law of inertia, if a car stops abruptly, the occupants and all other objects in the car maintain their forward momentum. In order for an occupant to come to rest, another collision is required. In a vehicle collision, the seat belt restrains the occupant and prevents him or her from impacting the steering wheel, dashboard or windshield, and helps absorb the occupant's forward momentum. Injuries are reduced as the impact force is distributed to the strongest parts of the body. An unrestrained occupant who is thrown from a vehicle is likely to be severely injured.

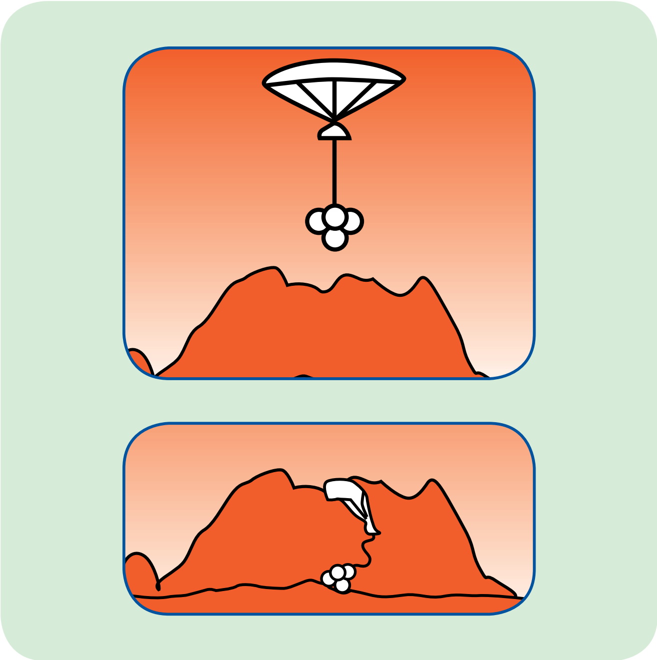
Car crash researchers estimate that seat belts reduce the risk of fatal injury to front-seat occupants by up to 45 per cent and the risk of serious injury by 50 per cent. The United States National Highway Traffic Safety Administration reports that 3 out of every 5 people killed in vehicle collisions in the US would have survived their injuries if they had buckled their seat belt.

Air Bags

In a car crash, the driver and occupant keep moving according to the law of inertia. A second collision is required to bring the occupant to rest. These secondary collisions are caused by impacting the steering wheel, dashboard, windshield, or other rigid structures. Since the secondary collisions happen very rapidly, a large force is being exerted over a very short period of time. Air bags can be used to minimize the force on a person involved in a collision. Air bags cushion the blow by increasing the amount of time during which the force is applied. Since the time of impact increases, the amount of force of the impulse decreases.

Research shows that air bags can save lives by reducing the risk of fatality in frontal impacts by about 30 per cent. However, air bags can be dangerous to children and small adults if they are not seated correctly when the air bag is activated. All occupants of vehicles with air bags need to be aware of the correct seating for maximum protection from collisions. Children and infants should be buckled into the rear seat in a properly installed car or booster seat. Infants should never ride in the front seat and should be carefully belted into a rear-facing safety seat.

Air bags are so effective that they were even used to cushion the impact for the Mars Pathfinder. Today, air bags are standard equipment in most automobiles, and some manufacturers are now including side air bags to help prevent injury caused by side impacts.



Head Restraints

Head restraints, or headrests, prevent soft tissue or "whiplash" injuries by stopping your head and neck from overextending in the event of a crash. Once again, in order to reduce the force of the impulse, a cushioning material is used to extend the duration of the impact, which reduces the force. However, head restraints only work if they're adjusted properly. The upper edge of the headrest should be the same height as the top of your head. The distance between your head and the headrest should be as small as possible and should not exceed 4 cm.

Rigid Occupant Cell

Safety systems are not just good practice for occupant cars. According to the latest Canadian statistics (for 1990 to 1996), 146 Canadians were killed on farms when the tractors they were driving rolled over and crushed them. Most of these deaths could have been prevented if the driver had been protected inside the tractor's cab by a rollover protective structure and the use of a seatbelt.

A rollover protective structure (ROPS) is a rigid structure built around the cab of a vehicle. In case of a rollover, the ROPS can support the weight of the vehicle and prevent the driver being crushed. devices in their work. They call the area inside the ROPS structure the "zone of protection", and appropriate precautions are taken so that the driver never leaves the safe zone. That includes the use of seat belts to keep the driver from being thrown against the ROPS frame, against the windshield, or completely out of the vehicle.

Child Safety Seats

According to Transport Canada, about 10,000 children 12 years and under are injured every year in traffic collisions in Canada. Children are not the same size as adults and require special consideration and protection when they are travelling in a vehicle. While it is mandatory for children under 5 years of age to be buckled in an approved child restraint system, as many as 90% of child safety seats are not properly installed or correctly used. Every forward-facing seat must be tethered to an anchor bolt; it's the law. The following table highlights the proper use of child restraint systems.

Protect Our Children. Always Use Children's Safety Seats Correctly.

	Type of Seat	Seat Position
Infants	Infants under 10 kg (22 lb) and 66 cm (26 in) must be in a rear-facing safety seat that is secured to the vehicle using the vehicle's restraint system (lap belt).	**Rear-facing only**
Toddlers	Toddlers 10 to 18 kg (20 to 40 lb) and 66 to 101 cm (26 to 40 in) tall must be in a forward-facing safety seat that must be tethered to the metal frame of the vehicle by an anchor bolt.	**Forward-facing**
Young Children	Children weighing more than 18 kg (40 lb) must be in a booster seat that is secured using the vehicle's restraint system.	**Forward-facing**
Older Children	Children weighing more than 32 kg (70 lb) may use a regular seat belt system. The lap belt should be worn low over the hips, and the shoulder belt should always be across the chest, never touching the face or neck.	**Forward-facing**

Manitoba Public Insurance, in collaboration with Manitoba Fire Departments, conducts free child car seat safety inspections at participating community fire stations. Call the MPI Road Safety Department at (204) 985-7199 for more information.

Help Protect Our Children!

Think About IT!

1. Research one of the safety devices, how it works, and statistics that show its effectiveness, future development, and safety standards. Make a poster and invite classmates and guests for a gallery walk to inspect the posters.
2. Design a car using the most modern safety features available.
3. Investigate NASCAR regulations that require drivers to adhere to strict safety protocols including rollover cages, seat belts, neck and head restraint systems, and crumple zones.
4. What are some other examples of devices that might use crumple zones, padded cushions, air bags, rollover cages, or bumpers?
5. Research the contribution of the following individuals to car safety.
   - a) Dr. Claire Straith
   - b) Bela Berenyi
   - c) Nils Bohlin
   - d) John Hetrick
   - e) Ralph Nader

Protecting Occupants

The Great Egg Drop Competition

According to Newton's physics, occupants in motion will continue in motion until they experience an impulse to reduce their momentum to zero. Safety engineers build protective devices that cushion the blow to reduce injury. Your task is to design and construct an occupant compartment that will protect the occupant (a raw egg) from injury (breaking) when dropped from some height.

Think About IT!

1. Should your package be made rigid or is it better if it collapses?
2. Should the egg be able to move or should it be held secure?
3. What kinds of materials or structures will absorb the shock of impact?
4. Is your compartment pleasing to look at? Remember, no one wants to buy an ugly car.

Guidelines

1. The compartment must be an original design.
2. Use common materials like cardboard, styrofoam, cotton, clear wrap, elastics, straws, ribbon, felt and tape to build your device.
3. The compartment must be no larger than a 10 cm x 10 cm x 10 cm cube.
4. You must be able to easily remove your occupant (the egg) from the compartment for inspection.
5. Drop your compartment from some height to a hard surface. The compartment that best protects the occupant from the highest drop wins.

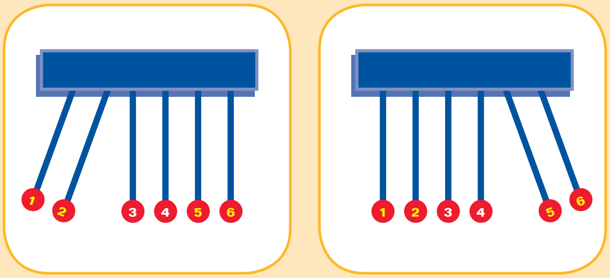
Scoring Rubric

1. **Originality** – Is the design unique, creative, and aesthetically pleasing? (maximum 25 points)
2. **Performance (Challenge One)** – All designs that protect the occupant to a height of 3 metres will be awarded full credit. (maximum 25 points)
3. **Performance (Challenge Two)** – The compartment that protects the occupant to the greatest height receives the most points. Points are prorated for compartments that work at a height of more than 3 metres but less than the greatest height. (maximum 25 points)
4. **Written report** – Include a written summary of the physics principles pertaining to your compartment. Try to use analogies to other safety devices. (maximum 25 points)
5. In case of a tie, the lightest compartment wins.

Momentum and Energy in a Collision

Think About IT!

The device in the figure is called Newton's cradle.



In each of the following cases, predict what will happen before you release the spheres.

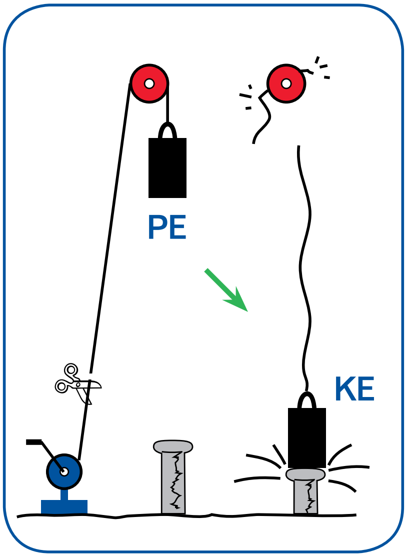
1. **Pull one sphere away from equilibrium and release.**
2. **Pull two spheres away and release them at the same time.**
3. **Pull three spheres away and release them at the same time.**
4. **Pull one sphere away from each side and release them at the same time.**

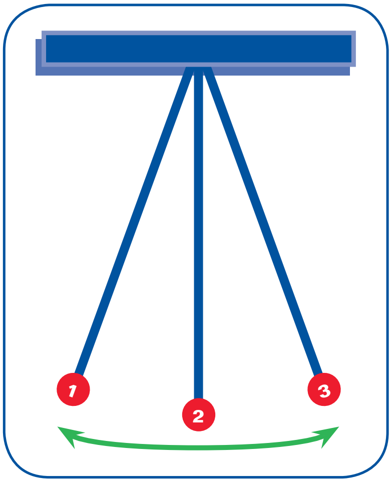
Collisions between objects are governed by laws of momentum and energy. Careful measurements before and after ideal collisions show that the momentum of all objects before a collision equals the momentum of all objects after the collision (provided there are no net external forces acting upon the objects). When a collision occurs in an isolated system, the total momentum of the system is always conserved. If there are only two objects involved in the collision, then the momentum lost by one object exactly equals the momentum gained by the other object.

Energy

At the beginning of this chapter we asked the question "what makes an object difficult to bring to rest?" We concluded that every moving object has a "quantity of motion" that was proportional to its velocity that we called momentum (mass x velocity). We also found that to change momentum we needed an impulse – a force that was applied over a period of time. All of these concepts fit very nicely with Newton's second law. However, we can think about motion differently.

If we push a book across the desk so that it accelerates, we give the book an impulse – we apply a force on the book for a period of time. However, the book also moves some distance during this time. That is, we also apply the force across a distance. Whenever we apply a force on an object across a distance, we say that we are doing work on that object. Work is the transfer of energy to an object by applying a force to the object through some distance. When we do work on the object, we change some condition of the object, either its position in space or its velocity. If we change its position, such as lifting a mass above the surface of the earth, the work we do is stored as gravitational potential energy (PE). If we change its velocity, the work is stored as kinetic energy (KE).



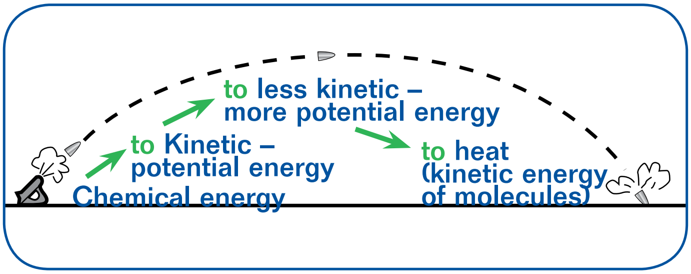


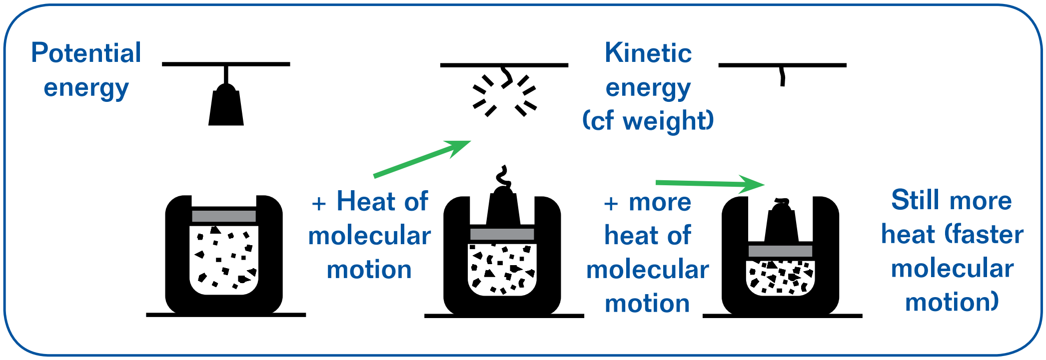
Suppose that a mass is attached to the end of a string and is set in motion as shown in the diagram. The pendulum comes to rest at the top of its swing (1) then falls back in the other direction. As the pendulum bob falls back, it reaches a maximum speed at the bottom of its swing (2). Then, it rises up the other side as its velocity decreases and once again comes to rest at the top of its swing (3). The motion repeats, and if there is no friction or outside forces (as in Galileo's thought experiments) the pendulum will swing forever. We can explain this motion by the principles of work and conservation of energy. Initially, we do work on the mass to raise it above its starting position. This work is stored as potential energy. When we release the mass, gravity does work on the mass and some potential energy is converted to kinetic energy. At the bottom of the swing all of the energy is stored as kinetic energy. In turn, the kinetic energy is transformed back into potential energy as the pendulum rises on the other side of its swing. The cycle repeats and, in the absence of any outside forces, the motion continues forever.

Energy can be transformed into other forms besides potential and kinetic. The kinetic energy of molecules in motion is known as heat and if we displace molecules of air by creating a pressure wave, the energy is transmitted as a sound wave.

René Descartes argued that energy must be conserved; otherwise, the world would run down like a tired old clock. Scientists, beginning with James Prescott Joule, have since made very careful measurements to show that energy is conserved in all interactions.

In the real world there are always outside forces. However, the principle of conservation of energy still remains valid. Energy can be stored in other forms besides gravity and motion. Energy can be stored electrically, chemically, in elastics and springs, as sound energy, and as thermal energy. If you rub your hands together very quickly, what do you feel? Your hands will feel warm as the kinetic energy of the motion of your hands is converted to thermal energy through friction. If you clap your hands together rapidly, what do you hear? If you stretch an elastic band and then release it, what happens? As you do work stretching the band, the energy is initially stored as potential energy in the band. Then, as you release the band the potential is transformed into the kinetic energy of the motion of the parts of the band as the ends accelerate toward each other. Finally, as the particles of the band collide, they compress the molecules of the air and the energy is transferred to your ear as a sound wave.





In a car crash, since the final kinetic energy and momentum of the vehicles are zero, all of the initial kinetic energy must be dissipated during the collision to other forms of energy. Unrestrained occupants and objects in the vehicle are like missiles with huge amounts of energy. In order to stop these moving objects, forces are required. These forces often cause severe personal and property damage.

Think About IT!

1. **What would the world be like if energy was not conserved? Give examples.**
2. **Where does the kinetic energy come from when a car accelerates from rest?**

PRACTICE

In the following cases, analyse the transformations of energy in terms of conservation of energy.

1. The motion of a car on a roller coaster. NOTE: This roller coaster was manufactured by Galileo's Ideal Physics Factory.

2. The motion of the bungee jumper.

3. Car A accelerates from a stoplight until it reaches the posted speed limit of 30 km/h. At the intersection, a pickup truck "runs" the stop sign. The driver of Car A applies the brakes and in an attempt to avoid the collision leaves skid marks on the road. A loud crash is heard as the car impacts the side panel of the truck.

4. A pole vaulter.

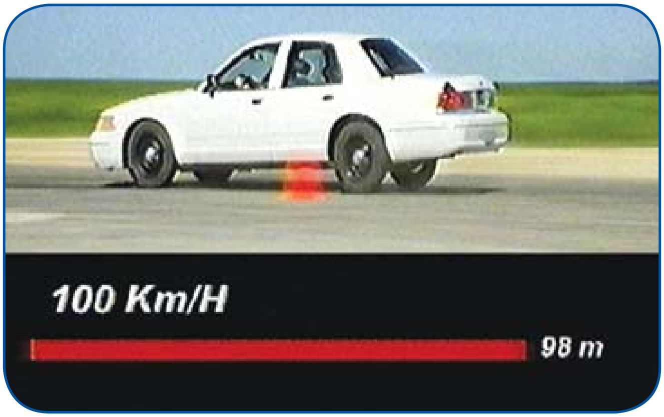
5. A child on a pogo stick.

6. Two cars with spring-loaded bumpers collide at a low speed and bounce off each other. Describe the collision in terms of the energy transformations that occur for the cars. What about the occupants of the cars?

Chapter 6

Braking

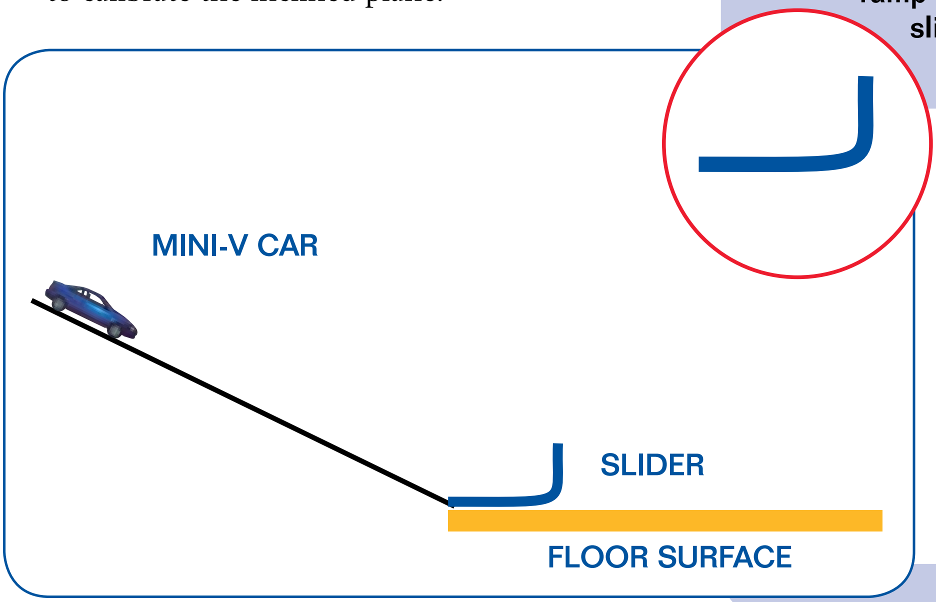
When a driver applies the brakes, the brake pads are pressed against part of a rotating wheel to apply a frictional force on the wheel. This frictional force causes the car to slow down and eventually stop. The distance the car travels while it is trying to stop is called the braking or stopping distance. The slope or grade of the road and the frictional resistance between the road and the car's tires can affect the braking distance. A car with new tires on a dry, level road will be less likely to skid and will stop more quickly than one with worn tires on a wet road.

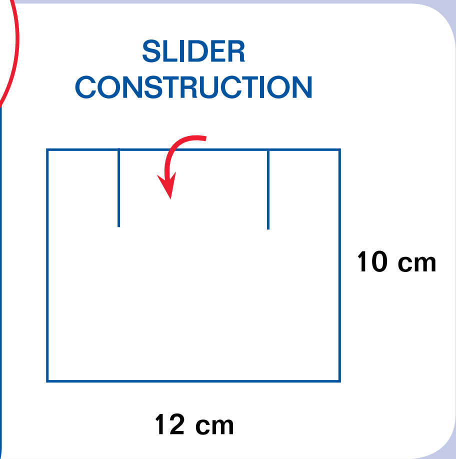


Investigation #6 BRAKING DISTANCE

The purpose of this investigation is to determine the relationship between the distance a car takes to brake and the velocity of the car. In Investigation #2 (p. 31), we calibrated an inclined plane such that we knew that the velocity of our car increased at a constant rate. In this activity, we can use the same procedure to calibrate the inclined plane.

Set up a mini-V activity as shown. Perform the investigation on a clean, dry surface to simulate good road conditions. A lab table or a tile surface will work just fine. To simulate braking, build a slider from a piece of 10 cm x 12 cm paper as shown in the diagram. Release the car down the ramp such that it collides with the slider at the bottom of the ramp.





Procedure

1. Release the car from the position for the first velocity (see calibrating the inclined plane on p. 28 to determine release points). Let the car collide with the braking sled at the bottom of the ramp.

2. Measure the braking distance (how far the slider moves from the end of the ramp) and repeat three times. Calculate the average braking distance.

3. Release the car from the next position up the ramp and repeat step #2. Continue until you have calculated the braking distance for 5 or 6 velocities.

4. Graph braking distance versus velocity.

Table A • Braking Distance

Relative Velocity	Trial #1 (cm)	Trial #2 (cm)	Trial #3 (cm)	Average (cm)	Comments
1					
2					
3					
4					
5					
6					

Think About IT!

1. Describe the shape of the graph. What can you conclude about the relationship between braking distance and velocity?
2. What does this mean in terms of how fast one drives a vehicle?

Challenge

The Effects of Friction on Braking

Design an investigation to examine the effects of friction on braking. How can you account for poor road conditions such as snow, ice and gravel?

Think About IT!

1. What do you conclude about the effects of snow, rain and ice on the braking distance?

Math Connection

We found in the previous activities that as speed increases, the braking distance increases at a faster rate. That is, if you double your speed, the braking distance more than doubles. In an ideal experiment, if you double your speed, the braking distance increases four times (2^2) and if your speed triples, your braking distance increases nine times (3^2).

1. Check your experimental data. How close is it to the ideal case?

A relationship where one factor increases at a faster rate than the other is called a power relationship. We can write this as a proportion statement which reads that:

"braking distance is proportional to the square of the velocity"

or in SYMBOLIC FORM

$$\mathbf{d} \propto \mathbf{v}^2$$

We also find that the braking distance depends on the friction between the two surfaces. Physicists account for the frictional effects by using a mathematical constant for different kinds of surfaces. In this way, the proportion can be represented by an equation such as:

$$\mathbf{d} = k\mathbf{v}^2$$

Where the constant k depends on the friction of the two surfaces in contact with each other, surfaces with a lot of friction have a low value for k, and slippery surfaces have a high value of k. Approximate values for the constant k can be found in the table. The values are given for velocities in m/s.

Rubber tire on:	Frictional constant k when velocity is in m/s
dry pavement	0.06
wet concrete	0.10
snow and ice	0.15

Example:

Find the braking distance for a car with a velocity of 50 km/h on dry pavement.

$d = kv^2$

v = 50 km/h = 50/3.6 m/s (change units to match)

v = 13.9 m/s

$d = 0.06 \times (13.92\ \text{m/s})^2$

d = 11.6 m

Therefore, the braking distance is 11.6 m in the direction of motion.

PRACTICE

1. Calculate the braking distance for a car driving at 10, 20, 30, 60, and 90 km/h.

2. Compare the braking distances for a car travelling at 30 km/h and a car travelling at 60 km/h. What do you conclude?

Total Stopping Distance

Our calculations of braking distances were for ideal cases only. In a real braking instance, a certain amount of time elapses before the driver recognizes a hazardous situation and applies the brakes. Consequently, the total stopping distance of a vehicle is made up of the distance the vehicle travels during the driver's reaction time plus the vehicle's braking distance. For example, let's suppose that a car is moving at 50 km/h on dry pavement. Suddenly, 34 m away, a small dog darts into the roadway. Typically, the driver takes 1.5 seconds to recognize and react to such a dangerous situation. The distance the vehicle travels during this reaction time can be found from our understanding of the relationship between distance, velocity and time. We know that:

$$\text{velocity} = \frac{\text{distance}}{\text{time}}$$

therefore

$$\text{distance} = \text{velocity x time}$$

And

reaction distance = 50 km/h x 1.5/3 600 h
(changing seconds to hours to match units)

reaction distance = 0.021 km or 21 m

Total Stopping Distance =
reaction distance + braking distance

Previously, we calculated the braking distance of a car travelling at 50 km/h on dry pavement as 11.6 m.

therefore

Total Stopping Distance = 21 m + 11.6 m = 32.6 m
A hazardous situation for the dog!

PRACTICE

1. Calculate the total stopping distance for a car that is traveling at 60 km/h on a rain-soaked road (use 1.5 seconds as the driver's reaction time).

Reaction Time

Driver Reaction Time

The driver reaction time is made up of three components: the vehicle response time, human perception time, and human reaction time.

Vehicle Response Time

Once the brakes are applied, the vehicle response time depends on the type and working order of the braking system including: tire tread and pressure, vehicle weight, the suspension system, and the braking technique applied by the driver. Vehicle response times will vary but a properly maintained vehicle will always respond better than one in poor condition.

Human Perception Time

Human perception time is how long the driver takes to see the hazard and then realize that it is a hazard. This perception time can vary considerably from about 0.5 of a seconds to as long as 3 or 4 seconds. In this time, the driver must decide if there is time to brake or whether steering is a better response. Moreover, drivers tend to hesitate when they encounter other vehicles or pedestrians in potentially hazardous situations because they wait for the vehicle or pedestrian to change their behaviour.

Human Reaction Time

Once the brain realizes that there is a hazardous condition, braking commences. Human reaction time is how long the body takes to move the foot from the accelerator to the brake pedal. Again, this reaction time can vary from person to person. Less experienced drivers are often slower to realize a dangerous situation.

Try IT!

You can find your reaction time as follows:

1. Hold your thumb and forefinger about 5 cm apart. Have a partner hold a metre-stick such that the zero mark is level with your thumb.
2. Without warning, your partner releases the metre-stick and you catch it by closing your thumb and forefinger. Record the distance mark where you catch it.
3. Repeat three times and take the average.
4. To find your reaction time, divide your catching distance in metres by 5 and take the square root of this number.

For example, you catch the metre-stick at the 17-cm mark. Your reaction time will be

$$\text{reaction time} = \sqrt{\frac{0.17}{5}} = 0.18 \text{ seconds}$$

Perception and reaction times also vary according to the surrounding environment of the driver. These times increase due to poor visibility, bad weather, alcohol, drugs, fatigue, and the driver's concentration and alertness.

Alertness

The driver who is alert and aware of his or her driving will have the best reaction time possible. At best, a good reaction time will be 0.7 seconds, of which 0.5 is perception time and 0.2 seconds is human reaction time. However, most hazardous situations are unexpected or surprise events that increase our perception time to 1.5 seconds or more.

A driver's alertness is also greatly influenced by the in-car environment. In-car displays, radio and CD controls, cell phones, and distractions caused by other occupants cause delays in reaction times of up to 1 second or more.

Poor Visibility

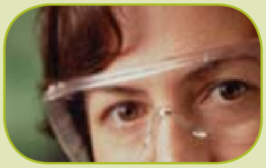
Poor weather also increases the driver's perception time in different ways, especially at night. Normally, we see an object when light reflects from the object back to our eye. Rain acts like a lens so that the light is scattered in different directions. As a result, visibility is reduced. Fog produces a similar phenomenon by scattering light and making it extremely difficult to see. Since blue light scatters more than yellow light, some experts recommend yellow fog lights. However, the illumination of yellow light is much lower and visibility is actually reduced. Fog droplets are generally too large to scatter light of different wavelengths, so yellow scatters the same as blue.

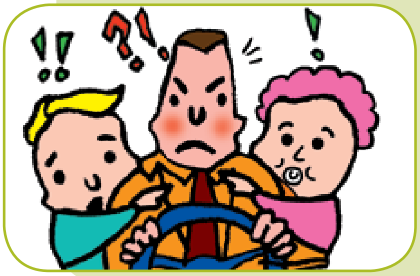
Poor weather conditions also create other kinds of visibility hazards. Rain influences our ability to see through the windshield of a car. Windshield wipers themselves obstruct our vision and the splash and sound of rain draws the attention of the driver away from the road. Poor visibility also forces drivers to concentrate their attention straight ahead in order to see where they are going. This decreases the peripheral field of vision so that it becomes more difficult to see another car or pedestrian approaching from the side.

Try IT!

Repeat the calculation of your reaction time under the following situations.

1. Simulate "poor visibility" by wrapping cellophane around a pair of safety goggles. What happens to your reaction time when your visibility is reduced?





2. Two persons act as distracters by asking the person who is testing their reaction time a series of "rapid fire" questions such as: "What did you do this weekend?", "What time did you get up?", "Who did you go out with?", and so on. Try answering the questions while a radio plays. What happens when you must concentrate on other things besides the reaction test?

Think About IT!

1. Why does a tailgating car usually not stop in time when the car ahead suddenly applies the brakes?

PRACTICE

1. Using the data from the braking distance investigation and your reaction time, calculate the total stopping distance for your car.

Relative Velocity	Braking Distance (cm)	Reaction Time (s)	Distance Travelled During Reaction Time (cm)	Total Braking Distance (cm)
1				
2				
3				
4				
5				
6				

2. If two cars are moving at 60 km/h, how far behind must the second car travel if it can safely stop?

3. For question #2, estimate the number of car lengths for each 10 km/h increase in speed.

4. A pedestrian wearing dark clothing at night is only visible at a distance of about 35 m to a driver using low beams. Calculate the maximum speed a car could have such that a driver could brake and avoid a collision (use a 1.5 second reaction time).

5. Some Driver Education experts recommend that "when the vehicle ahead of you passes a certain point, such as a sign, count 'one-thousand-one, one-thousand-two, one-thousand-three.' This takes about 3 seconds. If you pass this same point before you finish counting, you are following too closely." They also suggest a "4 second or more cushion" in inclement weather. Using the laws of physics and your understanding of braking distance, write a rationale for this rule.

Summary

Some people feel safer in large vehicles, such as Sport Utility Vehicles (SUVs). However, whether you are riding a tricycle or a 4 x 4, the laws of physics still apply. Understanding the laws of physics helps us to realize the importance of safe driving habits. It's simple – slow down before you hurt somebody, and leave a space cushion around your vehicle at all times. Arrive alive and enjoy life.

The Final Challenge

As a new physics expert, return to the car crash scenario in Chapter 1. Analyse the collision using your knowledge of Newton's laws, impulse, momentum and energy. Whose story is true, the motorcyclist's or the car driver's? Is that your final answer?

Report your findings to the class.

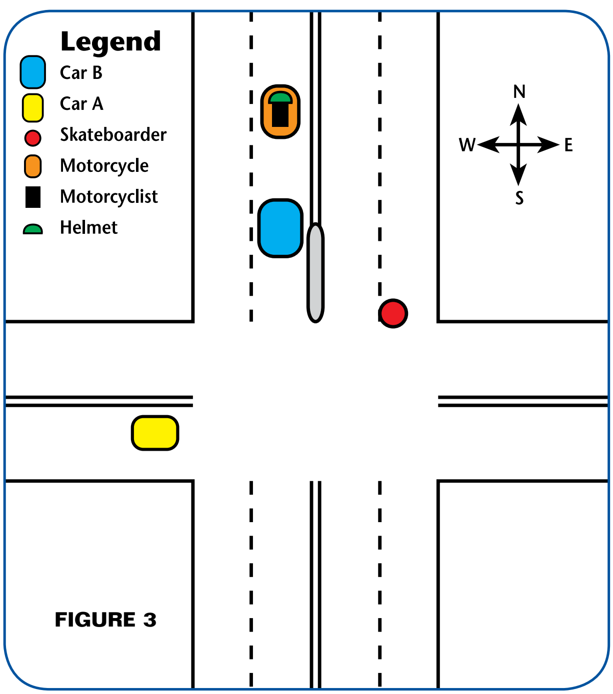


FIGURE 3

Car Crash After

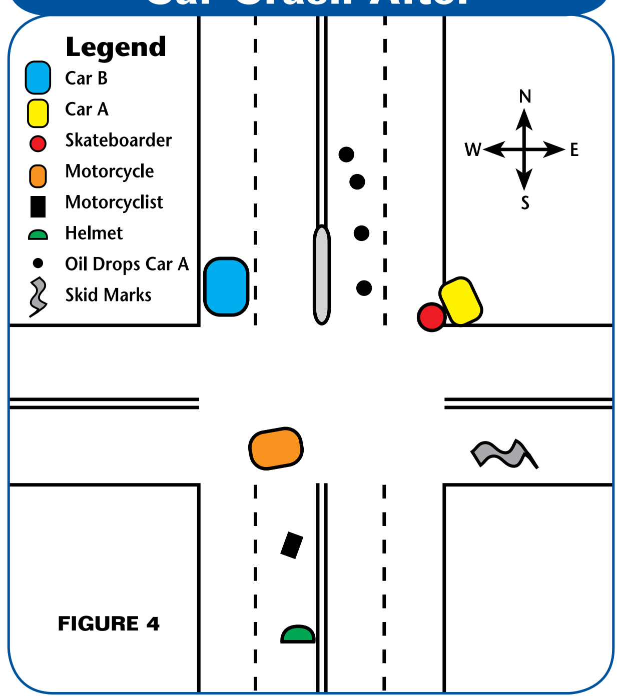


FIGURE 4

Chapter 7

Driving Responsibly

In today's fast-paced society, driving safely is everybody's responsibility. Our personal habits and lifestyle choices influence not only our own health, but sometimes the well-being of others. In society today, we must make difficult choices when innocent persons are victimized by the irresponsibility of others. Understanding the laws of physics enables us to make more informed choices when decisions need to be made to reduce personal injury, property damage, and emotional trauma caused by careless driving. In the following case studies, try to use your scientific knowledge to assess the situation and implement a plan of action to improve attitudes and personal habits, and to promote safe driving.

Case Study #1

Mr. Smith is 52 years of age. One night around 9:00 p.m., he was driving down Gladstone Street at the posted speed limit of 60 km/h. He promised to pick up his wife at 8:45 p.m. and he was late. Mr. Smith was listening to the hockey game on the car radio while he looked for his turn on Tower Blvd. Ms. Martin, wearing a dark blue coat, crossed in the middle of the street without looking both ways for oncoming traffic. When Mr. Smith noticed her, he applied the brakes but he did not stop in time, and his car collided with Ms. Martin. Police arrived and questioned Mr. Smith who said that he never saw the pedestrian. He admitted that he had a few beers before he left home, and a test revealed his blood-alcohol content was 0.06, below the legal limit of 0.08. The police did not charge him with any offences.

Challenge

After a large number of motor vehicle collisions similar to Mr. Smith's, the Chief of Police calls on you to submit a report to:

- **assess and clarify the problem**
- **review the police actions**
- **evaluate the available research**
- **develop a course of action to reduce such incidents**

Case Study #2

In your notebook, complete the following anticipation guide before and after you read the news article that follows on the next page.

Anticipation Guide

Drivers who have serious accidents are likely to be the common "troublemakers".	Before: After: Comments:
Criminal charges should be laid against young drivers who are involved in accidents.	Before: After: Comments:
The laws of physics suggest cars that are out of control can be brought back into control.	Before: After: Comments:
Most serious accidents caused by teenage drivers are the result of illegal narcotics or high blood-alcohol levels.	Before: After: Comments:
New driving laws, like Graduated Driver Licencing, drafted specifically for novice drivers are intended to maintain unreasonable control over young adults.	Before: After: Comments:

Lebanon teen-ager dies of injuries suffered in crash

By GISELLE GOODMAN and DAVID HENCH, Portland Press Herald Writers •

A 14-year-old Lebanon boy died Friday from injuries he suffered in a car crash the previous day.

Authorities are considering criminal charges against the 16-year-old driver, who got his license two months ago and was not supposed to have passengers. Colin Robinson, a junior firefighter known for his helpful nature, suffered fatal injuries in the crash at 11 a.m. Thursday on Long Swamp Road in Lebanon. Also injured were his brother Chadd Robinson, 17, and the driver, whose name has not been released because he is a juvenile facing the possibility of criminal charges. Both teen-agers were listed in stable condition Friday at local hospitals.

The three Lebanon teen-agers, students at Noble High School, were headed for the driver's house when he lost control of his Mercury Sable, which crashed into an oncoming car and landed in a water-filled ditch. Colin Robinson, who would have been 15 next month, died at 2 a.m. Friday at Maine Medical Center in Portland and his organs were donated to others. "He was dedicated to helping the community," said Jason Cole, Lebanon's assistant rescue chief. Robinson became a junior firefighter with the Lebanon Rescue Squad two years ago and wanted to be a firefighter or police officer when he grew up, Cole said. Whatever he became, Cole said, he was certain that Robinson would do something to help others. "He never caused any problems," Cole said. "He was just a good kid." In fact, when Cole blew a tire on Route 202 in Lebanon a few nights ago, it was Robinson, pedalling by on the bike he always rode, who stopped to help. Cole said all three of the boys in the car Thursday were good kids. "If (the driver) was thinking, he never would have done anything to hurt the other kids," Cole said. At Noble High on Friday, students who went to school knowing their classmates had been hurt in an accident learned with an awful jolt that Robinson, a freshman, was dead. "You're not sure if you talked to him just yesterday, or if you were mean to him," said 16-year-old Lindsey Adams. "I just haven't put it all together yet." Spencer Eldredge, a junior, said he didn't know Robinson well. But that didn't matter. He was still shaken by the news. "Death is just really final," Eldredge said. "I feel so bad for those who were pretty good friends with him. It puts a big black eye on the whole school year."

The school allowed grieving students to go home and offered counselling to students who needed it. Peggy Paine, of Crisis Response Services of York County, was one of those counsellors. She said the students she talked to were shocked and numbed by the news. "It's not normal and it's not fair," she said. "There have been a lot of tears, sobs and then the kids taking care of each other." Those who knew him might say Robinson would have been one of those caretakers. "Whenever we needed a hand," Cole said, "he was there to help." Maine State Police Trooper Mark Holmquist, the primary accident investigator, routinely uses photographs of fatal accidents to teach Noble High students about the dangers of driving too fast. But this one "may be too powerful," he said.

The three boys had stopped at the Cumberland Farms in Berwick to buy gas before heading to the driver's house in the middle of the school day, Holmquist said. He did not know if they made any other purchases or what they did earlier that morning. The driver was headed north when he drove off the side of the road, then overcorrected and hit an oncoming Honda. The driver of the Honda and his young daughter were not seriously injured. The Honda was travelling slowly and was able to stop before the cars collided, possibly avoiding additional deaths, Holmquist said. The side of the Mercury, between the front and rear passenger doors, slammed into the front of the Honda. Colin Robinson, the back-seat passenger, was fatally injured even though he was wearing a seatbelt. Investigators spent Friday reconstructing the accident to determine precisely what happened and how fast the car was going when it crashed. Preliminary estimates put the speed at between 60 and 80 mph, police said. The posted speed limit in that area is 35 mph.

Police are still trying to find out why the students were not in class and why they were headed to the driver's house. Holmquist said the driver's mother and possibly his father were out of town when the accident occurred. Since getting his license, the driver had not been convicted of any infractions, Holmquist said, although he will do more research to determine whether any complaints are pending. Under state law, young drivers cannot give rides to young people outside of their family for the first 90 days they have their license. "It's an opportunity to allow new, young drivers to get comfortable behind the wheel and not have peer pressures on them in the first couple months," said Domna Giatas, director of communications for the Secretary of State's Office. The law was passed in 2000, in part because speed is statistically the greatest threat to young drivers. Police met Friday with prosecutors from the York County District Attorney's Office to review the case. Officials expect to make a decision early next week about what charges, if any, to bring against the driver.

Staff Writer David Hench can be contacted at 791-6327 or at: dhench@mainetoday.com

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