

Ministry of Education



The Ontario Curriculum  
Grades 11 and 12

# Science

2000



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This publication is available on the Ministry of Education's website at <http://www.edu.gov.on.ca>.



# Introduction

*The Ontario Curriculum, Grades 11 and 12: Science, 2000* will be implemented in Ontario secondary schools starting in September 2001 for students in Grade 11 and in September 2002 for students in Grade 12. This document replaces the parts of the following curriculum guidelines that relate to the senior grades:

- *Science, Part 1: Program Outline and Policy, Intermediate and Senior Divisions, 1987*
- *Science, Part 6: Science, Grades 11 and 12, Basic Level, Intermediate and Senior Divisions, 1988*
- *Science, Part 7: Environmental Science, Grades 10 to 12, General Level, Intermediate and Senior Divisions, 1988*
- *Science, Part 8: Environmental Science, Grades 10 and 12, Advanced Level, Intermediate and Senior Divisions, 1988*
- *Science, Part 9: Applied Biology and Applied Chemistry, Grade 11, General Level, Intermediate and Senior Divisions, 1988*
- *Science, Part 10: Applied Physics and Technological Science, Grade 12, General Level, Intermediate and Senior Divisions, 1989*
- *Science, Part 11: Geology, Grade 12, General and Advanced Levels, Intermediate and Senior Divisions, 1988*
- *Science, Part 12: Biology, Grade 11, Advanced Level, and the OAC, Intermediate and Senior Divisions, 1987*
- *Science, Part 13: Chemistry, Grade 11, Advanced Level, and the OAC, Intermediate and Senior Divisions, 1987*
- *Science, Part 14: Physics, Grade 12, Advanced Level, and the OAC, Intermediate and Senior Divisions, 1988*
- *Science, Part 15: Science in Society, OAC, Intermediate and Senior Divisions, 1988*

This document is designed for use in conjunction with *The Ontario Curriculum, Grades 9 to 12: Program Planning and Assessment, 2000*, which contains information relevant to all disciplines represented in the curriculum. The planning and assessment document is available both in print and on the ministry's website, at <http://www.edu.gov.on.ca>.

## The Place of Science in the Curriculum

During the twentieth century, science has come to play an increasingly important role in the lives of all Canadians. It underpins many of the technologies that we now take for granted, from life-saving pharmaceuticals to computers and other information technologies. There is every reason to expect that science and its impact on our lives will continue to grow as we enter the twenty-first century. Consequently, scientific literacy for all has become the goal of science education throughout the world, and has been given expression in Canada in the *Common Framework of Science Learning Outcomes, K to 12: Pan-Canadian Protocol for Collaboration on School Curriculum* (Council of Ministers of Education, Canada, 1997). Scientific literacy can be defined as possession of the scientific knowledge, skills, and habits of mind required to thrive in the science-based world of the twenty-first century.

Achieving excellence in scientific literacy is not the same as becoming a science specialist. The notion of thriving in a science-based world applies as much to a small-business person, a lawyer, an elementary school teacher, or an office worker as it does to a doctor, an engineer, or a research scientist. While the specific knowledge and skills required for each of these occupations vary, the basic goal of thriving in a science-based world remains the same. Achievement of both excellence and equity underlies the goals of the new science program at the secondary level. Accordingly, science courses have been designed for a wide variety of students, taking into account their interests and possible postsecondary destinations. Some courses have been designed to serve as preparation for specialist studies in science-related fields; others have been designed for students intending to go on to postsecondary education but not to study science; still others have been designed with the needs of the workplace in mind. The overall intention is that all graduates of Ontario secondary schools will achieve excellence and a high degree of scientific literacy while maintaining a sense of wonder about the world around them. Accordingly, the curriculum reflects new developments on the international science scene and is intended to position science education in Ontario at the forefront of science education around the world.

Science has significant, though varied, connections with many other disciplines. Science is related in many ways to the economies of most nations, including Canada, and plays a major role in public and private decisions in many areas of society. It is critical, for example, to decisions and developments relating to sustainable development. Thus, science cannot be taught in isolation, but must be linked to other disciplines. Clearly, many topics studied in mathematics and technological education overlap with topics covered in science. Similar links exist with geography and other areas of social studies. Communication is, of course, extremely important in science, as it is in all disciplines – both in terms of reading and writing, and in the use of information technology for collecting, organizing, and presenting information. The newer aspects of the science curriculum – especially those that focus on science, technology, society, and the environment (STSE) – call for students to deal with the impacts of science on society and the environment, which includes both the natural environment and the workplace environment. This requirement brings in issues that relate to human values. Science can therefore not be viewed as merely a matter of “facts”; rather, it is a subject in which students learn to weigh the complex combinations of fact and value that developments in science and technology have given rise to in modern society.

Subject matter from any course in science can be combined with subject matter from one or more courses in other disciplines to create an interdisciplinary course. The policies and procedures regarding the development of interdisciplinary courses are outlined in the interdisciplinary studies curriculum policy document.

The secondary curriculum in science in Grades 9 to 12 builds on three basic goals that run through every grade and strand of the elementary curriculum and that reflect the essential triad of knowledge, skills, and the ability to relate science to technology, society, and the environment (STSE). In the secondary program, these goals vary somewhat according to the type of course, but they are always present in some form and serve to unify the program (see page 6). Science is approached in all courses not only as an intellectual pursuit but also as an activity-based enterprise operating within a social context.

The content of the secondary science program also builds on the five strands present in the elementary curriculum, although less emphasis is placed on technological education, which is a distinct discipline at the secondary level. The study of biology, chemistry, earth and space science, and physics in strands in the Grade 9 and 10 courses is expanded to the study of these subject areas in full courses in Grades 11 and 12. In addition, the transition between Grade 8 and Grade 9 courses and between the courses from Grades 9 to 12 is a smooth one because of the close alignment of both the elementary and the secondary program with the pan-Canadian *Common Framework of Science Learning Outcomes*.

# The Program in Science

## Overview

The overall aim of the secondary science program is to ensure scientific literacy for every secondary school graduate. This aim can be achieved by meeting three overall goals for every student. The secondary science program, from Grade 9 through Grade 12, is designed to promote these goals, which are as follows:

- to understand the basic concepts of science
- to develop the skills, strategies, and habits of mind required for scientific inquiry
- to relate science to technology, society, and the environment

These three goals are defined more specifically within the courses that make up the science program. Every strand, or broad curriculum area, of each course has three overall expectations and three groups of specific expectations that correspond to the three goals. These goals are also the basis on which student achievement in science is assessed.

Four types of courses are offered in the Grade 11 and 12 science program: university preparation, university/college preparation, college preparation, and workplace preparation. (See *The Ontario Curriculum, Grades 9 to 12: Program Planning and Assessment, 2000* for a description of the different types of secondary school courses.) A list of all Grade 11 and 12 science courses is given below. A chart showing prerequisites is given on page 8.

## Courses in Science, Grades 11 and 12

Grade	Course Name	Course Type	Course Code	Prerequisite
<b>Biology</b>				
11	Biology	University	SBI3U	Grade 10 Science, Academic
11	Biology	College	SBI3C	Grade 10 Science, Academic or Applied
12	Biology	University	SBI4U	Grade 11 Biology, University
<b>Chemistry</b>				
11	Chemistry	University	SCH3U	Grade 10 Science, Academic
12	Chemistry	University	SCH4U	Grade 11 Chemistry, University
12	Chemistry	College	SCH4C	Grade 10 Science, Academic or Applied
<b>Earth and Space Science</b>				
12	Earth and Space Science	University	SES4U	Grade 10 Science, Academic

Grade	Course Name	Course Type	Course Code	Prerequisite
<b>Physics</b>				
11	Physics	University	SPH3U	Grade 10 Science, Academic
12	Physics	University	SPH4U	Grade 11 Physics, University
12	Physics	College	SPH4C	Grade 10 Science, Academic or Applied
<b>Science</b>				
11	Science	University/College	SNC3M	Grade 10 Science, Academic or Applied
11	Science	Workplace	SNC3E	Grade 9 Science, Academic or Applied
12	Science	University/College	SNC4M	Grade 11 Science, University/College
12	Science	Workplace	SNC4E	Grade 11 Science, Workplace

*Note:* Each of the courses listed above is worth one credit.

**A Note About Credits.** Courses in Grades 11 and 12 are designed to be offered as full-credit courses. However, half-credit courses may be developed for specialized programs, such as school-work transition and apprenticeship programs, as long as the original course is not designated as a requirement for entry into a university program. Individual universities will identify the courses that are prerequisites for admission to specific programs. Such courses must be offered as full-credit courses, to ensure that students meet admission requirements.

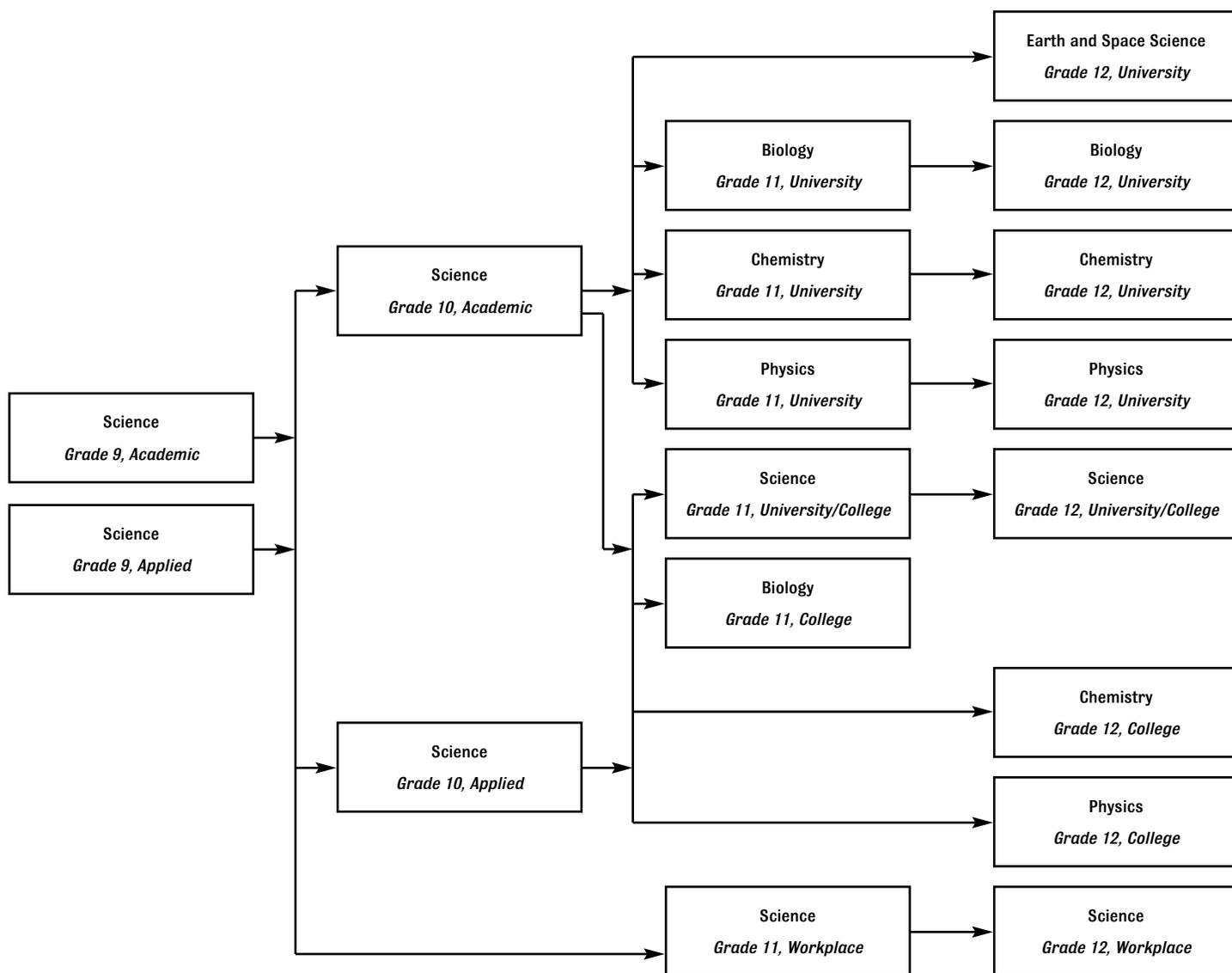
In Grades 9 to 12, half-credit courses, which require a minimum of fifty-five hours of scheduled instructional time, must adhere to the following conditions:

- The two half-credit courses created from a full course must together contain all of the expectations of the full course, drawn from all of the strands of that course and divided in a manner that best enables students to achieve the required knowledge and skills in the allotted time.
- A course that is a prerequisite for another course in the secondary curriculum may be offered as two half-credit courses, but students must successfully complete both parts of the course to fulfil the prerequisite. (Students are not required to complete both parts unless the course is a prerequisite for another course that they wish to take.)
- The title of each half-credit course must include the designation Part 1 or Part 2. A half-credit (0.5) will be recorded in the credit-value column of both the report card and the Ontario Student Transcript.

Boards will ensure that all half-credit courses comply with the conditions described above, and will report all half-credit courses to the ministry annually in the School September Report.

### Prerequisite Chart for Science, Grades 9–12

This chart maps out all the courses in the discipline and shows the links between courses and the possible prerequisites for them. It does not attempt to depict all possible movements from course to course.



### Teaching Approaches

It is important that students have opportunities to learn in a variety of ways: individually and cooperatively; independently and with teacher direction; through hands-on activities; and through the study of examples followed by practice. There is no single correct way to teach or to learn. The nature of the science curriculum calls for a variety of strategies for learning. The strategies should vary according to the curriculum expectations and the needs of the students.

The expectations in science courses call for an active, experimental approach to learning, and require all students to participate regularly in laboratory activities. Laboratory activities can reinforce the learning of scientific concepts and promote the development of the skills of

scientific investigation and communication. Where opportunity allows, students might be required, as part of their laboratory activities, to design and conduct research on a real scientific problem for which the results are unknown.

The goal of relating science to technology, society, and the environment (STSE) is an important new feature of this curriculum. In order to attain this goal, connections between science and technology and between science and the world beyond the school must be integrated into students' learning of scientific concepts and skills. Where possible, concepts should be introduced in the context of real-world problems and issues.

Students should also be provided with a variety of opportunities to broaden their understanding of scientific investigation. They should be encouraged to participate in research field trips and debates, and should have opportunities to interview people who are knowledgeable in specific areas of science, such as guest speakers at the school.

### **Curriculum Expectations**

The expectations identified for each course describe the knowledge and skills that students are expected to develop and demonstrate in their class work, on tests, and in various other activities on which their achievement is assessed and evaluated.

Two sets of expectations are listed for each *strand*, or broad curriculum area, of each course. The *overall expectations* describe in general terms the knowledge and skills that students are expected to demonstrate by the end of each course. The *specific expectations* describe the expected knowledge and skills in greater detail.

The specific expectations are organized under subheadings. This organization is not meant to imply that the expectations in any one group are achieved independently of the expectations in the other groups. The subheadings are used merely to help teachers focus on particular aspects of knowledge and skills as they plan learning activities for their students.

Many of the expectations are accompanied by examples, given in parentheses. These examples are meant to illustrate the kind of skill, the specific area of learning, the depth of learning, and/or the level of complexity that the expectation entails. They are intended as a guide for teachers rather than as an exhaustive or mandatory list.

In all courses, a list of expectations is given that precedes the strands. These expectations describe skills that are considered to be essential for scientific investigation (e.g., skills in research, in the use of materials, and in the use of units of measurement), and skills required for investigating possible careers in the subject area. These skills apply to all areas of course content and *must be developed in all strands* of the course. Teachers should ensure that students develop these skills in appropriate ways while achieving the curriculum expectations outlined in the strands. Assessment of students' mastery of these skills must be included in the evaluation of students' achievement of the expectations for the course.

## Strands

The expectations for the Grade 11 and 12 science courses are organized in five distinct but related strands. The strands are different for each course. The content of the strands includes, where possible, topics set out in the pan-Canadian *Common Framework of Science Learning Outcomes*. The strands for all the Grade 11 and 12 science courses are outlined in the following chart.

Course	Strand 1	Strand 2	Strand 3	Strand 4	Strand 5
Biology 11 U	Cellular Functions	Genetic Continuity	Internal Systems and Regulation	Diversity of Living Things	Plants: Anatomy, Growth, and Functions
Biology 11 C	Cellular Biology	Microbiology	Animal Anatomy and Physiology	Plant Structure and Physiology	Environmental Science
Biology 12 U	Metabolic Processes	Molecular Genetics	Homeostasis	Evolution	Population Dynamics
Chemistry 11 U	Matter and Chemical Bonding	Quantities in Chemical Reactions	Solutions and Solubility	Gases and Atmospheric Chemistry	Hydrocarbons and Energy
Chemistry 12 U	Organic Chemistry	Energy Changes and Rates of Reaction	Chemical Systems and Equilibrium	Electrochemistry	Structure and Properties
Chemistry 12 C	Matter and Qualitative Analysis	Organic Chemistry	Electrochemistry	Chemical Calculations	Chemistry in the Environment
Earth and Space Science 12 U	The Earth As a Planet	Introduction to Earth Sciences	Earth Materials	Internal and Surficial Earth Processes	Earth History
Physics 11 U	Forces and Motion	Energy, Work, and Power	Waves and Sound	Light and Geometric Optics	Electricity and Magnetism
Physics 12 U	Forces and Motion: Dynamics	Energy and Momentum	Electric, Gravitational, and Magnetic Fields	The Wave Nature of Light	Matter-Energy Interface
Physics 12 C	Mechanical Systems	Electricity and Electronics	Hydraulic and Pneumatic Systems	Communications Technology	Energy Transformations
Science 11 U/C	Everyday Chemicals and Safe Practice	Body Input and Body Function	Waste Management	Science and Space	Technologies in Everyday Life
Science 11 W	Materials and Safety	Electrical Circuits	Micro-organisms	The Immune System and Human Health	Human Impact on the Environment
Science 12 U/C	Organic Products in Everyday Life	Pathogens and Disease	Energy Alternatives and Global Impact	Communications Systems	Science and Contemporary Societal Issues
Science 12 W	Chemistry at Home and Work	Communications: Sounds and Pictures	Medical Technology	Gardening, Horticulture, Landscaping, and Forestry	Alternative Environments

*Note:* In the above chart, the following abbreviations are used: *U* for university preparation, *U/C* for university/college preparation, *C* for college preparation, and *W* for workplace preparation.

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# Biology

## Biology, Grade 11, University Preparation

(SBI3U)

This course furthers students' understanding of the processes involved in biological systems. Students will study cellular functions, genetic continuity, internal systems and regulation, the diversity of living things, and the anatomy, growth, and functions of plants. The course focuses on the theoretical aspects of the topics under study, and helps students refine skills related to scientific investigation.

**Prerequisite:** Science, Grade 10, Academic

***Throughout this course, students will:***

- demonstrate an understanding of safety practices consistent with Workplace Hazardous Materials Information System (WHMIS) legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., use proper techniques in preparing, using, and disposing of bacterial cultures);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., microscope, laboratory glassware, stethoscope, dissection instruments);
- demonstrate the skills required to plan and carry out investigations, using laboratory equipment safely, effectively, and accurately (e.g., conduct an experiment to determine the effects of quantity and quality of light on photosynthesis);
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., use characteristics of organisms and the principles and nomenclature of taxonomy to classify organisms; use proper terminology related to organs and tissues);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams;
- communicate the procedures and results of investigations and research for specific purposes using data tables and laboratory reports (e.g., report on an experimental investigation of the movement of materials across a cell membrane);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- select and use appropriate SI units (units of measurement of the *Système international d'unités*, or International System of Units);
- identify and describe science- and technology-based careers related to the subject area under study (e.g., biochemist, forester, geneticist, physiotherapist, oncologist, horticulturist).

## Cellular Functions

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of cell structure and function and the processes of metabolism and membrane transport;
- investigate the fundamental molecular principles and mechanisms that govern energy-transforming activities in all living matter, whether it be animal, plant, or microbial;
- demonstrate an understanding of the relationship between cell functions and their technological and environmental applications.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- describe how organelles and other cell components carry out various cell processes (e.g., digestion, transportation, gas exchange, excretion) and explain how these processes are related to the function of organs;
- identify and describe the structure and function of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids;
- describe the fluid mosaic structure of cell membranes, and explain the dynamics of passive transport (facilitated diffusion) and the processes of endocytosis and exocytosis of large particles;
- explain the flow of energy between photosynthesis and respiration;
- compare anaerobic respiration (including fermentation) and aerobic respiration and state the advantages and disadvantages for an organism or tissue of using either process;
- illustrate and explain important cellular processes (e.g., protein synthesis, respiration, lysosomal digestion), including their function in the cell, the ways in which they are interrelated, and the fact that they occur in all living cells.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- design and carry out an investigation on cellular function, controlling the major variables (e.g., examine the movement of substances across a membrane; measure a metabolic process such as fermentation);
- view and manipulate computer-generated, three-dimensional molecular models of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids;
- identify new questions and problems stemming from the study of metabolism in plant and animal cells (e.g., What is the relationship between chloroplasts and mitochondria in plant cells?);
- carry out, in a safe and accurate manner, biological tests for macromolecules found in living organisms (e.g., use iodine and Benedict's solution to test for carbohydrates; use Sudan IV to test for the presence of lipids).

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- present informed opinions on advances in cellular biology and possible applications through related technology (e.g., new treatments for cancer; the possibility of producing ethanol as a fuel; the uses of radioactive labelling, fluorescence of genetic material, or simulations of three-dimensional molecular structure);
- explain how scientific knowledge of cellular processes is used in technological applications (e.g., how knowledge of a particular microbe is used in biotechnological applications in the pulp and paper industry or in the clean-up of oil spills);
- analyse ways in which societal needs have led to technological advances related to cellular processes (e.g., document, using newspaper articles, the impact of public awareness on research to detect and treat diseases such as AIDS and hepatitis C).

## Genetic Continuity

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the necessity of meiosis and describe the importance of genes in transmitting hereditary characteristics according to Mendel's model of inheritance;
- perform laboratory studies of meiosis and analyse the results of genetic research related to the laws of heredity;
- outline the scientific findings and some of the technological advances that led to the modern concept of the gene and to genetic technology, and demonstrate an awareness of some of the social and political issues raised by genetic research and reproductive technology.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of the process and importance of mitosis (e.g., cell division and the phases of mitosis);
- explain how the concepts of DNA, genes, chromosomes, and meiosis account for the transmission of hereditary characteristics from generation to generation (e.g., explain how the sex of an individual can be determined genetically; demonstrate an understanding that the expression of a genetic disorder linked to the sex chromosomes is more common in males than in females);
- describe and explain the process of discovery (e.g., the sequence of studies and the knowledge gained) that led Mendel to formulate his laws of heredity;
- explain the process of meiosis in terms of the replication and movement of chromosomes;
- describe genetic disorders (e.g., Down syndrome, cystic fibrosis, muscular dystrophy, fragile X syndrome) in terms of the chromosomes affected, physical effects, and treatment;

- explain, using Mendelian genetics, the concepts of dominance, co-dominance, incomplete dominance, recessiveness, and sex-linkage;
- predict the outcome of various genetic crosses.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- explain the process of meiosis, with reference to a computer simulation or to their own investigations with a microscope (e.g., using slides of grasshopper testis, explain what happens in the first and second stages of prophase and metaphase and anaphase 2 in meiosis);
- solve basic genetic problems involving monohybrid crosses, incomplete dominance, co-dominance, dihybrid crosses, and sex-linked genes using the Punnett method;
- organize data (e.g., in a table) that illustrate the number of chromosomes in haploid cells and diploid cells, and the number of pairs of chromosomes in diploid cells, that occur in various organisms before, during, and as a result of meiosis;

- compile qualitative and quantitative data from a laboratory investigation on mono-hybrid and dihybrid crosses, and present the results, either by hand or computer (e.g., record observations using a “Virtual Fly” laboratory software package);
- research genetic technologies using sources from print and electronic media, and synthesize the information gained (e.g., describe the Human Genome Project, transgenics, or the process of genetic screening; list the advantages and disadvantages of cloning or the genetic manipulation of plants).
- describe and analyse examples of genetic technologies that were developed on the basis of scientific understanding (e.g., the improvement of an experimental procedure to extract DNA from bacterial or plant cells);
- identify and describe examples of Canadian contributions to knowledge about genetic processes (e.g., research into cystic fibrosis) and to technologies and techniques related to genetic processes (e.g., the invention of nuclear magnetic resonance [NMR]).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- summarize the main scientific discoveries of the nineteenth and twentieth centuries that led to the modern concept of the gene (e.g., the discoveries of Hugo de Vries, W.S. Sutton, Thomas Morgan, J. Muller, Barbara McClintock, Rosalind Franklin, James Watson, and Francis Crick);

## Internal Systems and Regulation

### Overall Expectations

By the end of this course, students will:

- describe and explain the major processes, mechanisms, and systems, including the respiratory, circulatory, and digestive systems, by which plants and animals maintain their internal environment;
- illustrate and explain, through laboratory investigations, the contribution of various types of systems and processes to internal regulation in plant and animal systems;
- evaluate the impact of personal lifestyle decisions on the health of humans, and analyse how societal concern for maintaining human health has advanced the development of technologies related to the regulation of internal systems.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- describe the process of ventilation and gas exchange from the environment to the cell (e.g., describe the pathway of oxygen from the atmosphere to the cell, and the roles of ventilation, haemoglobin, and diffusion in this process);
- explain the role of transport or circulatory systems in the transport of substances in an organism (e.g., explain how nutrients, respiratory gases, end products of metabolism, and hormones or regulatory chemicals are transported from one area in an organism to another);
- describe the importance of nutrients and digestion in providing substances needed for energy and growth (e.g., relate the need for carbohydrates in the diet to their role in cellular respiration; describe the many uses of proteins; describe how plants use nutrients);
- demonstrate an understanding of how fitness level is related to the efficiency of metabolism and of the cardiovascular and respiratory systems;
- describe how the use of prescription and non-prescription drugs can disrupt or help maintain homeostasis (e.g., describe the effects of acetylsalicylic acid, or ASA, on human systems).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- compare the anatomy of different organisms – vertebrate and/or invertebrate (e.g., carry out a dissection, or use a computer-simulated dissection, of a mammal or a fish to examine the heart, the pulmonary circulation system, the aorta, and other main arteries and veins, and compare the functions of the arteries and veins to those of xylem and phloem in plants);
- design and carry out, in a safe and accurate manner, an experiment on feedback mechanisms, identifying specific variables (e.g., investigate feedback controls by comparing resting rates of heartbeat and breathing with those after exercise, and then again after rest);
- select and integrate information about internal systems from various print and electronic sources, or from several parts of the same source (e.g., present information about special diets, such as those for vegans and diabetics; develop a pamphlet on how to treat the accidental ingestion of poisons).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- identify examples of technologies that have enhanced scientific understanding of internal systems (e.g., instruments used to monitor biological systems, such as the computer axial tomography [CAT] scanner or the stethoscope, and products used to alter or augment them, such as pharmaceuticals, prosthetics, and pacemakers; the use of radio-isotopes to identify and combat diseases);
- provide examples of Canadian contributions to the development of technology for examining internal systems (e.g., devices used in nuclear medicine);
- analyse and explain how societal needs have led to scientific and technological developments related to internal systems (e.g., explain how the need to maintain wellness in humans led to the development of dietary products and fitness equipment; analyse how social awareness of the importance of organ donation has led to improved techniques for transplanting organs, such as the liver);
- present informed opinions about how scientific knowledge of internal systems influences personal choices concerning nutrition and lifestyle (e.g., explain the advantages and disadvantages of taking steroids or amino acid supplements; explain the scientific reasons for committing personal time to exercise).

## Diversity of Living Things

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the diversity of living organisms through applying the concepts of phylogeny and taxonomy to the kingdoms of life (including Eubacteria and Archeabacteria) and viruses;
- use techniques of sampling and classification to illustrate the fundamental principles of taxonomy;
- relate the role of common characteristics and diversity within the kingdoms of life (including Eubacteria and Archeabacteria) to the importance of maintaining biodiversity within natural ecosystems, and explain the use of micro-organisms in biotechnology.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define the fundamental principles of taxonomy and phylogeny (e.g., provide definitions of concepts such as genus, species, and taxon, and explain how species are categorized and named according to structure and/or evolutionary history);
- compare and contrast the structure and function of different types of prokaryotic and eukaryotic cells (e.g., compare prokaryotic and eukaryotic cells in terms of genetic material, metabolism, and organelles/cell parts);
- describe selected anatomical and physiological characteristics of representative organisms from each life kingdom and a representative virus (e.g., describe gas exchange mechanisms and structures, or reproductive processes and components);
- compare and contrast the life cycles of representative organisms from each life kingdom and a representative virus (e.g., draw and label the life cycles of representative organisms, and make a chart comparing the features of the life cycles);
- explain the importance of sexual reproduction (including the process of meiosis) to variability within a population.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- demonstrate, through applying classification techniques and terminology, the usefulness of the system of scientific nomenclature in the field of taxonomy;
- classify representative organisms from each of the kingdoms (e.g., classify organisms according to their nutritional pattern, type of reproduction, habitat, and general structures);
- use appropriate sampling procedures to collect various organisms in a marsh, pond, or other ecosystem, and classify them following the principles of taxonomy.

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- explain the relevance of current studies of viruses and bacteria to the field of biotechnology (e.g., give examples of how viruses and bacteria are used in biotechnology);
- demonstrate an understanding of the connection between biodiversity and species survival (e.g., state the advantages to a population of having genetic variations

between individuals – such as the resistance to infection by “new” microorganisms, the resistance of insects to pesticides, or the resistance of bacteria to antibiotics; explain why some species and not others survive an environmental stress).

# Plants: Anatomy, Growth, and Functions

## Overall Expectations

By the end of this course, students will:

- describe the major processes and mechanisms by which plants grow, develop, and supply various products, including energy and nutrition, needed by other organisms;
- demonstrate an understanding, based in part on their own investigations, of the connections among the factors that affect the growth of plants, the uses of plants, and the ways in which plants adapt to their environment;
- evaluate how the energy and nutritional needs of a population influence the development and use of plant science and technology.

## Specific Expectations

### *Understanding Basic Concepts*

By the end of this course, students will:

- illustrate the process of succession and the role of plants in the maintenance of diversity and the survival of organisms;
- describe the structure and function of the components of each of the leaf, the stem, and the root of a representative vascular plant (e.g., describe the path of water from the soil through the plant);
- explain how non-vascular plants (e.g., multicellular algae, bryophytes) function without a specialized vascular system;
- differentiate between monocot and dicot plants by observing and comparing the structure of their seeds and identifying vascular differences between plants;
- describe the effects of growth regulators (e.g., auxins, gibberellins, cytokinins);
- describe and explain some of the food and industrial processes that depend on plants;
- describe and explain some of the uses of plant extracts in food and therapeutic products.

### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- design and carry out an experiment to determine the factors that affect the growth of a population of plants, identifying and controlling major variables (e.g., examine the effect on plant growth of the quantity of nutrients, or the quantity and quality of light, or temperature, or salinity);
- describe the nutrients required for the development of plants (e.g., describe the uses of nitrogen, phosphorus, and potassium in the plant, and relate them to fertilizer content; consider different stages in the growth of plants, from germination through growth, flowering, and fruit production, and indicate the appropriate fertilizer to be used at each stage);
- identify, using a microscope and models, the plant tissues in roots, stems, and leaves (e.g., use a microscope to identify tissues such as xylem and phloem throughout the plant);
- compile information about the chemical products derived from plants and, either by hand or computer, display the information in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (e.g., make a chart of plants and their related products).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- identify various factors that result in trade-offs in the development of food technologies (e.g., explain why vegetable growers might prefer varieties that “travel well” – that is, don’t spoil easily – over those with the most flavour or nutritional value);
- describe and explain ways in which society supports and influences plant science and technology (e.g., analyse the influence on food production technologies of the constant demand for fresh fruit at affordable prices);
- express opinions supported by their own research about the case for funding certain projects in plant science or technology rather than others (e.g., evaluate the relative merits, for funding purposes, of research projects on genetic manipulation of plants over projects related to the development of organic products);
- describe how a technology related to plants functions (e.g., long-term use of pesticides, including herbicides), and evaluate it on the basis of identified criteria such as safety, cost, availability, and impact on everyday life and the environment.

## Biology, Grade 11, College Preparation

(SBI3C)

This course focuses on the processes involved in biological systems. Students will learn concepts and theories as they conduct investigations in the areas of cellular biology, microbiology, animal anatomy and physiology, plant structure and physiology, and environmental science. Emphasis will be placed on the practical application of concepts, and on the skills needed for further study in various branches of the life sciences and related fields.

**Prerequisite:** Science, Grade 10, Academic or Applied

***Throughout this course, students will:***

- demonstrate an understanding of safety practices consistent with Workplace Hazardous Materials Information System (WHMIS) legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., follow safety procedures in handling, storing, and disposing of acids, bases, bacterial cultures, and bio-hazardous waste);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., microscope, laboratory glassware, stethoscope, dissection instruments);
- demonstrate the skills required to plan and carry out investigations, using laboratory equipment safely, effectively, and accurately (e.g., conduct an experiment to investigate gas production in the metabolic processes of plants);
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., identify chemical formulae for some important biochemical compounds; use correct terminology to describe the internal systems of organisms);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., construct a flow chart to describe representative mechanisms in living organisms, or a chart on the uses of microbes in biotechnological applications);
- communicate the procedures and results of investigations and research for specific purposes using data tables and laboratory reports (e.g., describe appropriate sampling techniques for classification of specimens in a local environment);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- select and use appropriate SI units;
- identify and describe science- and technology-based careers related to the subject area under study (e.g., cell technologist, chef, nutritionist, medical laboratory technician).

## Cellular Biology

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the basic processes of cellular biology, including membrane transport, cellular respiration, photosynthesis, and enzyme activity;
- investigate the factors that influence cellular activity using appropriate laboratory equipment and techniques;
- demonstrate an understanding of the importance of cellular processes in their personal lives, as well as in the development and application of biotechnology.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- state the principles of the cell theory;
- describe how organelles and other cell components carry out various cell processes;
- identify and describe the structure and function of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids (e.g., use models to represent the molecules or monomers of the polymers);
- describe the critical role of enzymes in biochemical reactions (e.g., describe the function of deaminase in the breakdown of amino acids; explain the role of enzymes as biological catalysts);
- identify cell processes and functions that use facilitated diffusion, osmosis, and active transport (e.g., describe the importance of facilitated diffusion in the movement of glucose across the membrane in the liver; describe the need for energy in the sodium-potassium pump);
- compare the chemical changes and energy transformations associated with the processes of respiration (aerobic and anaerobic) and photosynthesis;

- identify the role of compounds present in cellular respiration and photosynthesis (e.g., water, glucose, oxygen, carbon dioxide, and adenosine triphosphate [ATP]).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- analyse, based on their findings from a laboratory experiment, the effect of various factors (e.g., pH, temperature, and concentration of solute) on the rate of diffusion across a plasma membrane;
- prepare a wet mount of a stained specimen and, using a light microscope, identify some of the organelles of a cell (e.g., view with a light microscope nuclei and chloroplasts – ribosomes and mitochondria are more difficult to see);
- apply mathematical models to answer questions related to cell processes (e.g., calculate the magnification of a specimen; use the concept of exponential growth to explain the growth of cells);
- perform common laboratory procedures needed for the study of cell processes, using appropriate techniques (e.g., prepare buffer solutions needed for laboratory investigations into enzyme and membrane activity);

- investigate, through experimentation, the effect of environment on the action of enzymes (e.g., the effect of temperature or pH on the digestion of starch by saliva);
- conduct biological tests to identify macromolecules found in living organisms (e.g., use iodine and Benedict's solution to test for carbohydrates; use biuret solution to test for proteins).
- identify medical technologies based on cellular biology that are used in the diagnosis and treatment of disorders, and describe their benefits;
- apply scientific principles in describing and analysing the function of laboratory equipment and techniques used in cell biology.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- collaboratively or individually, research ways in which knowledge of cell processes and related technologies is relevant to their personal lives and the life of their community (e.g., investigate the effects of good nutrition on health using knowledge of metabolic processes and how they are clinically measured);

## Microbiology

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the characteristics of various micro-organisms, of their role in the environment, and of their influences on other organisms, including humans;
- analyse the development and physical characteristics of micro-organisms, using appropriate laboratory equipment and techniques;
- explain the role of micro-organisms with respect to human health and in technological applications in medicine, industry, and the environment.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- compare the structure and properties of the genetic material of viruses and bacteria with those of eukaryotic cells;
- illustrate the differences between representative bacteria (including Eubacteria and Archeobacteria), protists, viruses, and fungi by comparing their shape, motility, ecological role, and connection to human diseases;
- analyse and explain the different methods of reproduction in various types of viruses, monera, and fungi;
- describe the anatomy and physiology of representative organisms from monera, protists, fungi, and viruses;
- demonstrate an understanding of the vital role micro-organisms play in symbiotic relationships (e.g., gut enterobes, mycorrhizal fungi, and commensal phototrophs in coral polyp colonies);
- describe the role of viruses and bacteria in genetic manipulation, using their knowledge of DNA.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- identify specimens of monera, protists, and fungi by using prepared slides or wet mounts;
- prepare a laboratory culture of micro-organisms on agar using aseptic techniques;
- design and conduct an experiment to determine the effect of antibacterial agents on different bacterial cultures (e.g., determine the efficiency of various mouth-washes by observing the growth of bacteria on a nutrient agar);
- analyse the conditions needed by micro-organisms for growth, through laboratory activities (e.g., determine the optimal temperature for a particular bacterium to grow);
- work cooperatively to compile and organize data on micro-organisms from print and electronic sources, and communicate questions and results (e.g., research and describe how an industry uses microbes to make a product such as yogurt or hormones).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- evaluate the impact of viral, bacterial, and fungal infections on the health of host organisms, and on humans in particular (e.g., examine the relationship between the emergence of new species of bacteria and viruses and the use of antibiotics, and determine the health implications for human populations);
- describe some ways in which viruses, bacteria, and fungi are used in biotechnology (e.g., describe the use of viruses as vectors and as restriction enzymes);
- explain and illustrate the roles of viruses and bacteria in genetic engineering;
- evaluate the effects of large-scale use of fungicides and pesticides on the diversity of micro-organisms;
- describe some beneficial functions of micro-organisms in an ecosystem (e.g., the role of bacteria as decomposers).

## Animal Anatomy and Physiology

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the structure, function, and interactions of the main internal systems of humans and other animals;
- investigate, with the aid of laboratory procedures, the physiological mechanisms of animal systems that are responsible for the physical health of the individual;
- demonstrate an understanding of the connections among health, preventive measures, and treatment, and of their social and economic implications.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- describe the anatomy and physiology of the digestive, circulatory, excretory, respiratory, reproductive, and locomotion systems of humans and one other animal;
- explain mechanisms of interaction between animal systems (e.g., describe the exchanges between capillaries and tissues; explain the emulsification of lipids by bile);
- explain how the endocrine system and central nervous system help maintain homeostasis (e.g., describe how blood sugar levels are maintained by the liver and the pancreas);
- describe the causes and effects of common disorders of each system (e.g., explain the effects of lactose intolerance; describe the causes of heart murmurs).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use instruments accurately to collect data (e.g., use a stethoscope to find heart rate under various conditions; use blood simulation activities to determine blood types using antigens; use a sphygmomanometer to measure blood pressure);

- design and carry out an experiment related to animal physiology, identifying specific variables (e.g., demonstrate feedback controls by comparing resting heart rate with that after exercise, and then again after rest);
- carry out a dissection, or use a computer-simulated dissection, of a vertebrate to identify organs and establish relationships among structure, function, and health (e.g., dissect a mammal to identify and examine the components of the digestive system).

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- evaluate the influence of the media on attitudes towards nutrition (e.g., explain changing perspectives on dietary practices, such as awareness of the potential benefits of oat bran, or the desirability of unsaturated fats over saturated fats);
- describe how a technology related to the treatment of internal systems functions (e.g., kidney dialysis, the use of artificial hearts and artificial blood) and evaluate it on the basis of identified criteria such as safety, cost, availability, and impact on everyday life and the environment.

## Plant Structure and Physiology

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the diversity of plants, and of their internal transport systems, reproduction, and growth;
- analyse the factors influencing the growth and maintenance of plants, using appropriate laboratory equipment and techniques;
- evaluate the roles of plants in the urban community, in various technologies and industries, and in natural ecosystems.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- illustrate how plants are classified by identifying similar and different characteristics of different types of plants (e.g., make a chart to demonstrate the unique structure and development of plants; examine the life cycle of plants);
  - describe the structure and physiology of plant tissues;
  - describe in words and/or diagrams the life cycle of plants, and differentiate between such divisions of plants as ferns and horsetails;
  - describe the processes of growth and differentiation in plants (e.g., describe the differentiation of germ cells in various tissues; compare meristem cells with elongated cells);
  - explain the role of tropisms in plants (e.g., describe the reaction of a plant to light, to gravity, or to humidity).
- identify new questions or problems arising from the study of the growth and maintenance of plants (e.g., What organic growing methods are both reliable and cost efficient? How can biotechnology be used in the cultivation of plants?);
  - on the basis of information gathered from print and electronic sources, develop, present, and defend a position or course of action related to the maintenance of plants (e.g., justify or argue against the use of pesticides to control insect infestation);
  - analyse the chemical and physical elements that contribute to plant production in the agriculture and forestry industries;
  - investigate tropisms by growing plants from seeds;
  - analyse plant metabolic processes, in a laboratory environment, by measuring the volume of gases produced and absorbed;
  - distinguish between monocot and dicot plants, using appropriate instruments and sources.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- apply appropriate sampling procedures when collecting specimens of plants (e.g., collect specimens to illustrate the diversity of fallen cones in a selected coniferous stand);

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- identify personal activities that may be influenced by their scientific study of plants (e.g., investigate the many issues involved in choosing to use chemical fertilizers and pesticides on the lawn; describe the scientific, psychological, and aesthetic benefits and/or drawbacks of maintaining plants in living spaces and classrooms);
- outline the use of plants in the food, textile, pharmaceutical, and fresh produce industries;
- explain the vital role of aquatic and marsh plants in the purification of urban, industrial, and agricultural waste or run-off water;
- evaluate the importance of plant diversity both in maintaining natural ecosystems and in providing sources of medicines;
- analyse the risks and benefits to society of using various agricultural technologies (e.g., genetically altered plants or growth hormones), and propose actions that can be taken to minimize risks.

## Environmental Science

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of factors that influence the sustainability of the natural environment and evaluate their importance;
- analyse how various factors influence the relationships between organisms and the natural environment;
- explain why it is important to be aware of the impact of human activities on the natural environment.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of the fundamental principles of taxonomy by classifying organisms from a local ecosystem;
- assess the impact of agriculture on the natural environment;
- use energy pyramids to explain the production, distribution, and use of food resources in a food chain (e.g., draw energy pyramids that illustrate human consumption of corn, of cattle, and of salmon);
- explain the ecological role of representative organisms from each of the kingdoms of life (including Eubacteria and Archeobacteria);
- describe and explain examples of symbiotic relationships (e.g., explain the mutual benefits of nitrogen-fixing bacteria in the root nodule of legumes, or the negative impact of a parasite on its host);
- describe the flow of matter through the biogeochemical cycles (e.g., describe and illustrate the carbon, nitrogen, phosphorus, and water cycles);
- describe and evaluate factors contributing to environmental resistance and a change in the carrying capacity of ecosystems;

- define population growth and identify the factors that influence it;
- compare the major Canadian biomes (e.g., tundra, taiga, deciduous forest, grasslands, and temperate rain forest) in terms of vegetation, climate, type of soil, agriculture, and forestry.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate sampling techniques to collect specimens in a local environment, and classify the specimens by applying the principles of taxonomy;
- conduct a laboratory investigation into competition between species and evaluate the findings (e.g., investigate the competition for food among the different species of paramecium);
- investigate and explain how a change in one population can affect the entire food web (e.g., explain how the killing off of species of fish by the lamprey eel affects fishing communities; explain the effects of the introduction of zebra mussels into the Great Lakes);
- represent the growth of populations using mathematical calculations, graphs and charts of population growth and life cycles, and survivorship curves;

- investigate, independently or collaboratively, the effect that human population growth has on the environment and the quality of life (e.g., examine effects, such as the movement or elimination of wildlife and plants, that are caused by the encroachment of human populations on ecosystems).
- evaluate the local use of natural and technologically engineered pesticides and herbicides;
- analyse, from a variety of perspectives, the risks and benefits to society and the environment of applying scientific knowledge of ecosystems or introducing a particular technology (e.g., examine the effects of recycling programs, or of introducing a species into an environment).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- independently or collaboratively, synthesize and evaluate information from a variety of sources about an environmental and population-related issue, and propose a course of action (e.g., analyse a natural preserve as to its *raison d'être*, such as the species being conserved);

## Biology, Grade 12, University Preparation

(SBI4U)

This course provides students with the opportunity for in-depth study of the concepts and processes associated with biological systems. Students will study theory and conduct investigations in the areas of metabolic processes, molecular genetics, homeostasis, evolution, and population dynamics. Emphasis will be placed on achievement of the detailed knowledge and refined skills needed for further study in various branches of the life sciences and related fields.

**Prerequisite:** Biology, Grade 11, University Preparation

***Throughout this course, students will:***

- demonstrate an understanding of safety practices consistent with Workplace Hazardous Materials Information System (WHMIS) legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., use proper techniques in handling, storing, and disposing of bacteria, chemicals, and bio-hazardous waste);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., use molecular models to represent functional groups; perform gel electrophoresis or DNA extraction);
- demonstrate the skills required to plan and carry out investigations, using laboratory equipment safely, effectively, and accurately (e.g., conduct an experiment to investigate the effect of temperature on enzymes);
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., use chemical formulae for biological molecules);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., create a chart of hormone actions, or of homologous and analogous structures; create a timeline of recent discoveries in biotechnology);
- communicate the procedures and results of investigations and research for specific purposes using data tables and laboratory reports (e.g., report on an experimental investigation of the effect of chemical stimuli on invertebrates, or the causes of fluctuation of a population);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- select and use appropriate SI units;
- identify and describe science- and technology-based careers related to the subject area under study (e.g., genetic engineer, biochemist, genetic counsellor, microbiologist, pharmacologist, histologist, immunologist, palaeontologist, population ecologist, nutritionist).

## Metabolic Processes

### Overall Expectations

By the end of this course, students will:

- describe the structure and function of the macromolecules necessary for the normal metabolic functions of all living things, and the role of enzymes in maintaining normal metabolic functions;
- conduct laboratory investigations into the transformation of energy in the cell, including photosynthesis and cellular respiration, and into the chemical and physical properties of biological molecules;
- explain ways in which knowledge of the metabolic processes of living systems can contribute to technological development and affect community processes and personal choices in everyday life.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- apply the laws of thermodynamics to the transfer of energy in the cell, particularly with respect to respiration and photosynthesis;
- identify the functional groups within biological molecules (e.g., hydroxyl, carbonyl, carboxyl, amino, phosphate) and explain how they contribute to the function of each molecule (e.g., use molecular models to determine whether a molecule is polar or non-polar, and relate this property to diffusion through a plasma membrane);
- describe the chemical structure, mechanisms, and dynamics of enzymes in cellular metabolism (e.g., the function of enzymes in metabolic reactions in mitochondria or chloroplasts);
- identify and describe the four main types of biochemical reactions: redox, hydrolysis, condensation, and neutralization;
- describe how such molecules as glucose, ATP, pyruvic acid, NADH, and oxygen function within energy transformations in the cell, and explain the roles of such cell components as mitochondria, chloroplasts, and enzymes in the processes of cellular respiration and photosynthesis;

- compare matter and energy transformations associated with the processes of cellular respiration (aerobic and anaerobic) and photosynthesis (e.g., for each process, compare the role of oxygen and the role of organelles, such as mitochondria and chloroplasts).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- formulate operational definitions of the terms related to metabolic processes (e.g., use the following terms in relation to cell metabolism: *electronegativity, isomer, functional group, polymer, organic acid, organic base, solubility, enzyme, substrate, reaction rate*);
- investigate the structures of biological molecules and functional groups using computer-generated, three-dimensional images and/or by building molecular models (e.g., simple carbohydrates, amino acids, simple polypeptides);
- investigate and explain the relationship between metabolism and the structure of biomolecules, using problem-solving techniques (e.g., analyse the difference between the metabolic rates of sweet corn and starchy corn);

- design and carry out an experiment related to a cell process (e.g., enzyme activity, membrane transport), controlling the major variables and adapting or extending procedures where required (e.g., conduct an experiment to find optimal conditions [pH, concentration, and temperature] for various enzymes and membrane transport);
- determine the similarities and differences between mitochondria and chloroplasts (e.g., compare the structure and function of a mitochondrion and a chloroplast by examining micrographs and identifying reactants, products, and pathways);
- interpret qualitative and quantitative observations, gathered through investigation, of the products of cellular respiration and photosynthesis (e.g., type and quantity produced) and, either by hand or by computer, compile and display the results in an appropriate format.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- relate knowledge gained from their current studies of metabolism to their learning in the fields of chemical thermodynamics and physical energy;
- describe technological applications of enzyme activity in the food and pharmaceutical industries (e.g., the production of dairy products using micro-organisms; the use of yeast to make bread; the use of enzymes to control reaction rates in the pharmaceutical industry);
- explain the relevance, in their personal lives and the life of the community, of the study of cell biology and related technologies (e.g., explain how their learning about metabolic processes is relevant to their personal choices about exercise, diet, and the use of pharmacological substances).

## Molecular Genetics

### Overall Expectations

By the end of this course, students will:

- explain the concepts of gene and gene expression and the roles of DNA, RNA, and chromosomes in cellular metabolism, growth, and division, and demonstrate an awareness of the universality of the genetic code;
- explain, through laboratory activities and conceptual models, processes within the cell nucleus;
- describe some of the theoretical issues surrounding scientific research into genetic continuity; the general impact and philosophical implications of the knowledge gained; and some of the issues raised by related technological applications.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- compare the structure and function of RNA and DNA, and explain their roles in protein synthesis;
- describe the current model of DNA replication and methods of repair following an error;
- explain the steps involved in protein synthesis (e.g., transcription and translation) and the control mechanisms for genetic expression using regulatory proteins (e.g., lac operon, tryp operon);
- describe how mutagens such as radiation and chemicals can change the genetic material in cells by causing mutations (e.g., point mutations and frame-shifts);
- demonstrate an understanding of genetic manipulation, and of its industrial and agricultural applications (e.g., describe the processes involved in cloning, or in sequencing of DNA bases; explain the processes involved in the manipulation of genetic material and protein synthesis; explain the development and mechanisms of the polymerization chain reaction);

- describe the functions of the cell components used in genetic engineering (e.g., the roles of plasmids, restriction enzymes, recombinant DNA, and vectors);
- outline contributions of genetic engineers, molecular biologists, and biochemists that have led to the further development of the field of genetics (e.g., the findings of Cohen-Boyer [1973], Chilton [1981], and Stanford [1988]; transfer of the somatotropine gene [1990]).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- illustrate the genetic code by examining/analysing a segment of DNA (e.g., compare base sequences of DNA for an enzyme in humans and another animal; compare base sequences in DNA in order to recognize an anomaly);
- interpret micrographs that demonstrate the cellular structures involved in protein synthesis;
- investigate and analyse the cell components involved in protein synthesis, using laboratory equipment safely and appropriately (e.g., extract DNA; compare different proteins; separate DNA or polypeptides using electrophoresis);

- describe the major findings that have arisen from the Human Genome Project (e.g., create a timeline of the project, or make a chart of the discoveries).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- explain the roles of evidence, theories, and paradigms in the development of scientific knowledge about genetics (e.g., explain the impact of cloning a sheep on the theory of differentiation; explain the impact of the discovery of the structure of DNA as the universal molecule for living organisms);
- describe the principal elements of the Canadian regulations on biotechnological products, and explain their implications (e.g., consult Environment Canada or Food and Health Canada for the regulations; or use current websites for agencies such as Agriculture Canada that list new products).

# Homeostasis

## Overall Expectations

By the end of this course, students will:

- describe and explain the physiological and biochemical mechanisms involved in the maintenance of homeostasis;
- analyse, through experiments and the use of models, the feedback mechanisms that maintain chemical and physical homeostasis in animal systems;
- analyse how environmental factors (physical, chemical, emotional, and microbial) and technological applications affect/contribute to the maintenance of homeostasis, and examine related societal issues.

## Specific Expectations

### *Understanding Basic Concepts*

By the end of this course, students will:

- describe the anatomy and physiology of the endocrine and nervous systems, and explain their roles in homeostasis;
- explain the action of hormones in the female and male reproductive systems, including the feedback mechanisms involved;
- explain the role of the kidney in maintaining water and ion balance;
- describe and explain homeostatic processes involved in maintaining water, ionic, thermal, and acid-base equilibria in response to both a changing environment and medical treatments (e.g., explain the feedback mechanisms involved in water balance or thermo-regulation; explain the buffering system of blood; describe the effect of disorders of the nervous system or endocrine system; describe how chemotherapy affects homeostasis);
- describe the mammalian immunological response to a viral or bacterial infection;
- predict the impact of environmental factors such as allergens on homeostasis within an organism.

### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- construct a model that illustrates the essential components of the homeostatic process (e.g., use a flow chart to describe representative feedback mechanisms in living things);
- design and carry out an experiment to investigate a feedback system (e.g., record physiological effects of drinking coffee);
- design and conduct an experiment using invertebrates to study the response to external stimuli (e.g., instinctive behaviour in response to chemical stimuli or light);
- compile and display, either by hand or computer, data and information about homeostatic phenomena in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (e.g., create a chart of hormones showing the source, stimulation, target organ, action and nature, and related disorders for each; make a graph of the reaction time of the pupil of the eye when stimulated by light of different colours; create a chart of allergies and the foods that trigger them).

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- synthesize case study information about the effects of taking chemical substances to enhance performance or improve health (e.g., explain the effect of steroids on health; debate the wisdom of taking large quantities of vitamins or amino acids; describe substances people use to cope with stress);
- present informed opinions about problems related to the health industry, health legislation, and personal health (e.g., describe issues related to transplants or kidney dialysis; discuss the difficulties in treating neurological and infectious diseases);
- describe some Canadian contributions to knowledge and technology in the field of homeostasis (e.g., the discovery of a new blood stem cell; the discovery of insulin).

## Evolution

### Overall Expectations

By the end of this course, students will:

- analyse evolutionary mechanisms, and the processes and products of evolution;
- evaluate the scientific evidence that supports the theory of evolution;
- analyse how the science of evolution can be related to current areas of biological study, and how technological development has extended or modified knowledge in the field of evolution.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define the concept of speciation and explain the mechanisms of speciation;
- describe, and put in historical and cultural context, some scientists' contributions that have changed evolutionary concepts (e.g., describe the contributions – and the prevailing beliefs of their time – of Lyell, Malthus, Lamarck, Darwin, and Gould and Eldridge);
- analyse evolutionary mechanisms (e.g., natural selection, sexual selection, genetic variation, genetic drift, artificial selection, biotechnology) and their effects on biodiversity and extinction (e.g., describe examples that illustrate current theories of evolution, such as the darkening over time, in polluted areas, of the pigment of the peppered moth, an example of industrial melanism);
- explain, using examples, the process of adaptation of individual organisms to their environment (e.g., explain the significance of a short life cycle in the development of antibiotic-resistant bacteria populations).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- outline evidence and arguments pertaining to the origin, development, and diversity of living organisms on Earth (e.g., evaluate current evidence that supports the theory of evolution and that feeds the debate on gradualism and punctuated equilibrium);
- identify questions to investigate that arise from concepts of evolution and diversity (e.g., Why do micro-organisms evolve so quickly? What factors have contributed to the dilemma that pharmaceutical companies face in trying to develop new antibiotics because so many micro-organisms are resistant to existing antibiotics?);
- solve problems related to evolution using the Hardy-Weinberg equation;
- develop and use appropriate sampling procedures to conduct investigations into questions related to evolution (e.g., to determine the incidence of various hereditary characteristics in a given population), and record data and information;

- formulate and weigh hypotheses that reflect the various perspectives that have influenced the development of the theory of evolution (e.g., apply different theoretical models for interpreting evidence).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- relate present-day research and theories on the mechanisms of evolution to current ideas in molecular genetics (e.g., relate current thinking about adaptations to ideas about genetic mutations);
- describe and analyse examples of technology that have extended or modified the scientific understanding of evolution (e.g., the contribution of radiometric dating to the palaeontological analysis of fossils).

## Population Dynamics

### Overall Expectations

By the end of this course, students will:

- analyse the components of population growth, and explain the factors that affect the growth of various populations of species;
- investigate, analyse, and evaluate populations, their interrelationships within ecosystems, and their effect on the sustainability of life on this planet;
- evaluate the carrying capacity of the Earth, and relate the carrying capacity to the growth of populations, their consumption of natural resources, and advances in technology.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- explain the concepts of interaction (e.g., competition, predation, defence mechanisms, symbiotic relationships, parasitic relationships) among different species of animals and plants;
- describe characteristics of a population, such as growth, density, distribution, carrying capacity, minimum/viable size;
- compare and explain the fluctuation of a population of a species of plant, wild animal, and micro-organism, with an emphasis on such factors as carrying capacity, fecundity, and predation;
- use examples of the energy pyramid to explain production, distribution, and use of food resources;
- explain the demographic changes observed over the past ten thousand years (e.g., explain the effect on populations of such factors as epidemics, the rise of agriculture, the Industrial Revolution, and the development of modern medicine);
- explain, using demographic principles, problems related to the rapid growth of human populations and the effects of that growth on future generations (e.g., relate the carrying capacity of the Earth to the growth of populations and their consumption of resources).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use conceptual and mathematical models to determine the growth of populations of various species in an ecosystem (e.g., use the concepts of exponential, sigmoid, and sinusoidal growth to describe and predict various populations);
- determine experimentally the characteristics of population growth of two populations (e.g., examine the population cycles of a predator and a prey, or those of two populations that compete for food);
- using the ecological hierarchy for living things, evaluate how a change in one population can affect the entire hierarchy both physically and economically (e.g., the effects of the killing off of species of fish by lamprey eels, or the results of the introduction of zebra mussels into the Great Lakes);
- investigate, individually or collaboratively, the effects of human population growth on the environment and the quality of life (e.g., effects on ecosystems, such as the elimination of wildlife, plants, and farmland; causes and effects of ozone depletion or acid rain).

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- analyse Canadian investments in human resources and agricultural technology in a developing country (e.g., investigate Canadian International Development Agency [CIDA]-funded projects in a developing country);
- describe examples of stable food-production technologies that nourish a dense and expanding population;
- outline the advances in medical care and technology that have contributed to an increase in life expectancy, and relate these developments to demographic issues.

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# Chemistry

# Chemistry, Grade 11, University Preparation

(SCH3U)

This course focuses on the concepts and theories that form the basis of modern chemistry. Students will study the behaviours of solids, liquids, gases, and solutions; investigate changes and relationships in chemical systems; and explore how chemistry is used in developing new products and processes that affect our lives and our environment. Emphasis will also be placed on the importance of chemistry in other branches of science.

**Prerequisite:** Science, Grade 10, Academic

***Throughout this course, students will:***

- demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., safely disposing of hazardous solutions; correctly interpreting Workplace Hazardous Materials Information System [WHMIS] symbols), and using appropriate personal protection (e.g., wearing safety goggles);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., use a balance to accurately measure the mass of a precipitate);
- demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., plan and carry out an investigation to determine the percentage composition of a compound);
- demonstrate a knowledge of emergency laboratory procedures;
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., present a detailed experimental report according to specified standards);
- compile and interpret data or other information gathered from print, laboratory, and electronic sources, including Internet sites, to research a topic, solve a problem, or support an opinion (e.g., research the uses of the most common products of the refining of petroleum);
- communicate the procedures and results of investigations for specific purposes by displaying evidence and information, either in writing or using a computer, in various forms, including flow charts, tables, graphs, and laboratory reports (e.g., draw a graph of the relationship between the volume and pressure of a fixed amount of gas at constant temperature);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- select and use appropriate SI units (units of measurement of the *Système international d'unités*, or International System of Units);
- identify and describe science- and technology-based careers related to the subject area under study (e.g., describe careers in the area of hydrocarbons and energy, such as chemical engineering, or careers in transportation related to the research and development of new fuels).

## Matter and Chemical Bonding

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the relationship between periodic tendencies, types of chemical bonding, and the properties of ionic and molecular compounds;
- carry out laboratory studies of chemical reactions, analyse chemical reactions in terms of the type of reaction and the reactivity of starting materials, and use appropriate symbols and formulae to represent the structure and bonding of chemical substances;
- describe how an understanding of matter and its properties can lead to the production of useful substances and new technologies.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the relationship among atomic number, mass number, atomic mass, isotope, and radio isotope;
- demonstrate an understanding of the periodic law, and describe how electron arrangement and forces in atoms can explain periodic trends such as atomic radius, ionization energy, electron affinity, and electronegativity;
- demonstrate an understanding of the formation of ionic and covalent bonds and explain the properties of the products;
- explain how different elements combine to form covalent and ionic bonds using the octet rule;
- demonstrate an understanding of the relationship between the type of chemical reaction (e.g., synthesis, decomposition, single and double displacement) and the nature of the reactants;
- relate the reactivity of a series of elements to their position in the periodic table (e.g., compare the reactivity of metals in a group and metals in the same period; compare the reactivity of non-metals in a group).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to chemical reactions (e.g., *electronegativity, chemical bond, periodic trend, ionization energy, electron affinity*);
- analyse data involving periodic properties such as ionization energy and atomic radius in order to recognize general trends in the periodic table;
- predict the ionic character or polarity of a given bond using electronegativity values, and represent the formation of ionic and covalent bonds using diagrams;
- draw Lewis structures, construct molecular models, and give the structural formulae for compounds containing single and multiple bonds;
- write, using IUPAC or traditional systems, the formulae of binary and tertiary compounds, including those containing elements with multiple valences, and recognize the formulae in various contexts;
- predict the products of, and write chemical equations to represent, synthesis, decomposition, substitution, and double displacement reactions, and test the predictions through experimentation;

- investigate through experimentation the reactions of elements (e.g., metals) to produce an activity series.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- identify chemical substances and reactions in everyday use or of environmental significance (e.g., fertilizers, greenhouse gases, photosynthesis);
- relate common names of substances to their systematic names (e.g., *muratic acid* and *hydrochloric acid*; *baking soda* and *sodium bicarbonate*);
- evaluate and compare the reactivity of metals and alloys (e.g., gold in jewellery, iron and stainless steel), and explain why most metals are found in nature as compounds;
- demonstrate an understanding of the need for the safe use of chemicals in everyday life (e.g., cleaners in the home, pesticides in the garden).

## Quantities in Chemical Reactions

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the mole concept and its significance in the analysis of chemical systems;
- carry out experiments and complete calculations based on quantitative relationships in balanced chemical reactions;
- demonstrate an awareness of the importance of quantitative chemical relationships in the home or in industry.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of Avogadro's number, the mole concept, and the relationship between the mole and molar mass;
- explain the relationship between isotopic abundance and relative atomic mass;
- distinguish between the empirical formula and the molecular formula of a compound;
- explain the law of definite proportions;
- state the quantitative relationships expressed in a chemical equation (e.g., in moles, grams, atoms, ions, or molecules).
- balance chemical equations by inspection;
- balance simple nuclear equations;
- calculate, for any given reactant or product in a chemical equation, the corresponding mass or quantity in moles or molecules of any other reactant or product;
- solve problems involving percentage yield and limiting reagents;
- compare, using laboratory results, the theoretical yield of a reaction (e.g., of steel wool and copper II sulfate solution) to the actual yield, calculate the percentage yield, and suggest sources of experimental error.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to chemical calculations (e.g., *stoichiometry, percentage yield, limiting reagent, mole, atomic mass*);
- determine percentage composition of a compound through experimentation, as well as through analysis of the formula and a table of relative atomic masses (e.g., composition of a hydrate);
- solve problems involving quantity in moles, number of particles, and mass;
- determine empirical formulae and molecular formulae, given molar masses and percentage composition or mass data;
- give examples of the application of chemical quantities and calculations (e.g., in cooking recipes, in industrial reactions, in prescription drug dosages);
- explain how different stoichiometric combinations of elements in compounds can produce substances with different properties (e.g., water and hydrogen peroxide, carbon monoxide and carbon dioxide);
- identify everyday situations and work-related contexts in which analysis of unknown substances is important (e.g., quality control of composition of products; drug analysis in forensics).

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

## Solutions and Solubility

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the properties of solutions, the concept of concentration, and the importance of water as a solvent;
- carry out experiments and other laboratory procedures involving solutions, and solve quantitative problems involving solutions;
- relate a scientific knowledge of solutions and solubility to everyday applications, and explain how environmental water quality depends on the concentrations of a variety of dissolved substances.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of the importance of water as a universal solvent and describe the properties of this liquid (e.g., polarity, hydrogen bonding);
- explain solution formation that involves the dissolving of ionic or non-ionic substances in water (e.g., oxygen in water, salt in water) and the dissolving of non-polar solutes in non-polar solvents (e.g., grease in gasoline);
- describe the dependence on temperature of solubility in water for solids, liquids, and gases;
- describe common combinations of aqueous solutions that result in the formation of precipitates;
- demonstrate an understanding of the Arrhenius and Bronsted-Lowry theories of acids and bases;
- explain qualitatively, in terms of degree of dissociation, the difference between strong and weak acids and bases;
- demonstrate an understanding of the operational definition of pH (i.e.,  $\text{pH} = -\log_{10}[\text{H}^+]$ ).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to aqueous solutions (e.g., *concentration, solubility, conjugate acid, precipitate*);
- solve problems involving concentration of solutions and express the results in various units (e.g., moles per litre, grams per 100 mL, parts per million [and billion], mass or volume per cent);
- prepare solutions of required concentration by dissolving a solid solute or diluting a concentrated solution;
- determine, through experiments, qualitative and quantitative properties of solutions (e.g., perform a qualitative analysis of ions in a solution; plot solubility curves for some common solutes in water), and solve problems based on such experiments;
- represent precipitation reactions by their net ionic equations;
- determine through experimentation the effect of dilution on the pH of an acid or a base;

- write balanced chemical equations for reactions involving acids and bases (e.g., dissociation, displacement, and neutralization reactions);
- solve stoichiometry problems involving solutions;
- use a titration procedure to determine the concentration of an acid or base in solution (e.g., acetic acid in vinegar).
- explain the origins of pollutants in natural waters (e.g., landfill leachates, agricultural run-off), and identify the allowable concentrations of metallic and organic pollutants in drinking water;
- describe the technology and the major steps involved in the purification of drinking water and the treatment of waste water;
- explain hardness of water, its consequences (e.g., pipe scaling), and water-softening methods (e.g., ion exchange resins).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- supply examples from everyday life of solutions involving all three states (e.g., carbonated water, seawater, alloys, air);
- describe examples of solutions for which the concentration must be known and exact (e.g., intravenous solutions, drinking water);

## Gases and Atmospheric Chemistry

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the laws that govern the behaviour of gases;
- investigate through experimentation the relationships among the pressure, volume, and temperature of a gas, and solve problems involving quantity of substance in moles, molar masses and volumes, and the gas laws;
- describe how knowledge of gases has helped to advance technology, and how such technological advances have led to a better understanding of environmental phenomena and issues.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- explain different states of matter in terms of the forces between atoms, molecules, and ions;
- describe the gaseous state, using kinetic molecular theory, in terms of degree of disorder and types of motion of atoms and molecules;
- describe the quantitative relationships that exist among the following variables for an ideal gas: pressure, volume, temperature, and amount of substance;
- explain Dalton's law of partial pressures;
- state Avogadro's hypothesis and describe his contribution to our understanding of reactions of gases;
- identify the major and minor components of the atmosphere.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to gases (e.g., *standard temperature*, *standard pressure*, *molar volume*, *ideal gas*);
- use and interconvert appropriate units to express pressure (e.g., pascals, atmospheres, mm Hg) and temperature (e.g., Celsius and Kelvin scales);

- determine through experimentation the quantitative and graphical relationships among the pressure, volume, and temperature of an ideal gas;
- solve quantitative problems involving the following gas laws: Charles's law, Boyle's law, the combined gas law, Gay-Lussac's law, Dalton's law of partial pressures, the ideal gas law;
- perform stoichiometric calculations involving the quantitative relationships among the quantity of substances in moles, the number of atoms, the number of molecules, the mass, and the volume of the substances in a balanced chemical equation;
- determine the molar volume of a gas through experimentation (e.g., calculate the molar volume of hydrogen gas from the reaction of magnesium with hydrochloric acid).

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- describe natural phenomena (e.g., geysers, volcanic eruptions) and technological products (e.g., rocket engine, carbonated drinks, air bags) associated with gases;

- explain Canadian initiatives to improve air quality (e.g., the recycling of chlorofluorocarbons, the Montreal Protocol);
- identify technological products and safety concerns associated with compressed gases (e.g., propane tanks, medical oxygen tanks, welders' acetylene tanks);
- describe how knowledge of gases is applied in other areas of study (e.g., meteorology, medical anaesthetics, undersea exploration).

## Hydrocarbons and Energy

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the structure and properties of hydrocarbons, especially with respect to the energy changes that occur in their combustion;
- describe and investigate the properties of hydrocarbons, and apply calorimetric techniques to the calculation of energy changes;
- evaluate the impact of hydrocarbons on our quality of life and the environment through an examination of some of their uses.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- identify the origins and major sources of organic compounds;
- demonstrate an understanding of the particular characteristics of the carbon atom, especially with respect to bonding in both aliphatic and cyclic alkanes, including structural isomers;
- describe some of the physical and chemical properties of hydrocarbons (e.g., solubility in water, density, melting point, boiling point, and combustibility of the alkanes);
- compare the energy changes observed when chemical bonds are formed and when they are broken, and relate these changes to endothermic and exothermic reactions;
- explain how mass, heat capacity, and change in temperature of an object determine the amount of heat it gains or loses;
- identify ways in which reactants, products, and a heat term are combined to form thermochemical equations representing endothermic and exothermic chemical changes.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to hydrocarbons and the energy changes involved in their combustion (e.g., *organic compound*, *saturated hydrocarbons*, *unsaturated hydrocarbons*, *isomer*, *heat capacity*);
- name, using the IUPAC nomenclature system, and draw structural representations for, aliphatic and cyclic hydrocarbons containing no more than ten carbon atoms in the main chain, with or without sidechains;
- use molecular models to demonstrate the arrangement of atoms in isomers of hydrocarbons (e.g., structural and cis-trans isomers);
- determine through experimentation some of the characteristic properties of saturated and unsaturated hydrocarbons (e.g., compare the products obtained when bromine is added to cyclohexane and cyclohexene separately);
- carry out an experiment involving the production or combustion of a hydrocarbon (e.g., formation of acetylene, burning paraffin) and write the corresponding balanced chemical equation;

- write balanced chemical equations for the complete and incomplete combustion of hydrocarbons;
- gather and interpret experimental data and solve problems involving calorimetry and the equation  $Q = mc\Delta T$  (e.g., calculate the energy liberated in the combustion of paraffin in J/g).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe the steps involved in refining petroleum to obtain gasoline and other useful fractions (e.g., butane, furnace oil, industrial chemicals and solvents);
- demonstrate an understanding of the importance of hydrocarbons as fuels (e.g., propane for barbecues) and in other applications, such as the manufacture of polymers, and identify the risks and benefits of these uses to society and the environment.

## Chemistry, Grade 12, University Preparation

(SCH4U)

This course enables students to deepen their understanding of chemistry through the study of organic chemistry, energy changes and rates of reaction, chemical systems and equilibrium, electrochemistry, and atomic and molecular structure. Students will further develop problem-solving and laboratory skills as they investigate chemical processes, at the same time refining their ability to communicate scientific information. Emphasis will be placed on the importance of chemistry in daily life, and on evaluating the impact of chemical technology on the environment.

**Prerequisite:** Chemistry, Grade 11, University Preparation

***Throughout this course, students will:***

- demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., safely disposing of organic solutions; correctly interpreting Workplace Hazardous Materials Information System [WHMIS] symbols), and using appropriate personal protection (e.g., wearing safety goggles);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., use a calorimeter in heat transfer experiments);
- demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., select and use apparatus safely in an experiment to determine the mass of a metal deposited by electroplating);
- demonstrate a knowledge of emergency laboratory procedures;
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., use the Valence Shell Electron Pair Repulsion [VSEPR] model to predict the shapes of molecules);
- compile and interpret data or other information gathered from print, laboratory, and electronic sources, including Internet sites, to research a topic, solve a problem, or support an opinion (e.g., research the uses of the most commonly synthesized organic compounds);
- communicate the procedures and results of investigations for specific purposes by displaying evidence and information, either in writing or using a computer, in various forms, including flow charts, tables, graphs, and laboratory reports (e.g., construct visual models that explain intermolecular and intramolecular forces);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- select and use appropriate SI units;
- identify and describe science- and technology-based careers related to the subject area under study (e.g., describe careers related to thermochemistry, such as chemical engineering).

## Organic Chemistry

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the structure of various organic compounds, and of chemical reactions involving these compounds;
- investigate various organic compounds through research and experimentation, predict the products of organic reactions, and name and represent the structures of organic compounds using the IUPAC system and molecular models;
- evaluate the impact of organic compounds on our standard of living and the environment.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- distinguish among the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides, by name and by structural formula;
- describe some physical properties of the classes of organic compounds in terms of solubility in different solvents, molecular polarity, odour, and melting and boiling points;
- describe different types of organic reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis;
- demonstrate an understanding of the processes of addition and condensation polymerization;
- describe a variety of organic compounds present in living organisms, and explain their importance to those organisms (e.g., proteins, carbohydrates, fats, nucleic acids).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to organic chemistry (e.g., *functional group, polymer*);
- use the IUPAC system to name and write appropriate structures for the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, amides, and simple aromatic compounds;
- build molecular models of a variety of aliphatic, cyclic, and aromatic organic compounds;
- identify some nonsystematic names for organic compounds (e.g., *acetone, isopropyl alcohol, acetic acid*);
- predict and correctly name the products of organic reactions, including substitution, addition, elimination, esterification, hydrolysis, oxidation, and polymerization reactions (e.g., preparation of an ester, oxidation of alcohols with permanganate);
- carry out laboratory procedures to synthesize organic compounds (e.g., preparation of an ester, polymerization).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- present informed opinions on the validity of the use of the terms *organic*, *natural*, and *chemical* in the promotion of consumer goods;
- describe the variety and importance of organic compounds in our lives (e.g., plastics, synthetic fibres, pharmaceutical products);
- analyse the risks and benefits of the development and application of synthetic products (e.g., polystyrene, aspartame, pesticides, solvents);
- provide examples of the use of organic chemistry to improve technical solutions to existing or newly identified health, safety, and environmental problems (e.g., leaded versus unleaded gasoline; hydrocarbon propellants versus chlorofluorocarbons [CFCs]).

## Energy Changes and Rates of Reaction

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the energy transformations and kinetics of chemical changes;
- determine energy changes for physical and chemical processes and rates of reaction, using experimental data and calculations;
- demonstrate an understanding of the dependence of chemical technologies and processes on the energetics of chemical reactions.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- compare the energy changes resulting from physical change, chemical reactions, and nuclear reactions (fission and fusion);
- explain Hess's law, using examples;
- describe, with the aid of a graph, the rate of reaction as a function of the change of concentration of a reactant or product with respect to time; express the rate of reaction as a rate law equation (first- or second-order reactions only); and explain the concept of half-life for a reaction;
- explain, using collision theory and potential energy diagrams, how factors such as temperature, surface area, nature of reactants, catalysts, and concentration control the rate of chemical reactions;
- analyse simple potential energy diagrams of chemical reactions (e.g., potential energy diagrams showing the relative energies of reactants, products, and activated complex);
- demonstrate understanding that most reactions occur as a series of elementary steps in a reaction mechanism.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to the energetics of chemical reactions (e.g., *enthalpy*, *activated complex*);
- write thermochemical equations, expressing the energy change as a  $\Delta H$  value or as a heat term in the equation;
- determine heat of reaction using a calorimeter, and use the data obtained to calculate the enthalpy change for a reaction (e.g., neutralization of sodium hydroxide and hydrochloric acid);
- apply Hess's law to solve problems, including problems that involve data obtained through experimentation (e.g., measure heats of reaction that can be combined to yield the  $\Delta H$  of combustion of magnesium);
- calculate heat of reaction using tabulated enthalpies of formation;
- determine through experimentation a rate of reaction (e.g., of hydrogen peroxide decomposition), and measure the effect on it of temperature, concentration, and catalysis.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- compare conventional and alternative sources of energy with respect to efficiency and environmental impact (e.g., burning fossil fuels, solar energy, nuclear fission);
- describe examples of technologies that depend on exothermic or endothermic changes (e.g., hydrogen rocket fuel, hot and cold packs);
- describe the use of catalysts in industry (e.g., catalytic converters) and in biochemical systems (e.g., enzymes) on the basis of information gathered from print and electronic sources;
- describe examples of slow chemical reactions (e.g., rusting), rapid reactions (e.g., explosions), and reactions whose rates can be controlled (e.g., food decay, catalytic decomposition of automobile exhaust).

## Chemical Systems and Equilibrium

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the concept of chemical equilibrium, Le Chatelier's principle, and solution equilibria;
- investigate the behaviour of different equilibrium systems, and solve problems involving the law of chemical equilibrium;
- explain the importance of chemical equilibrium in various systems, including ecological, biological, and technological systems.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- illustrate the concept of dynamic equilibrium with reference to systems such as liquid-vapour equilibrium, weak electrolytes in solution, and chemical reactions;
- demonstrate an understanding of the law of chemical equilibrium as it applies to the concentrations of the reactants and products at equilibrium;
- demonstrate an understanding of how Le Chatelier's principle can predict the direction in which a system at equilibrium will shift when volume, pressure, concentration, or temperature is changed;
- identify, in qualitative terms, entropy changes associated with chemical and physical processes;
- describe the tendency of reactions to achieve minimum energy and maximum entropy;
- describe, using the concept of equilibrium, the behaviour of ionic solutes in solutions that are unsaturated, saturated, and super-saturated;
- define constant expressions, such as  $K_{sp}$ ,  $K_w$ ,  $K_a$ , and  $K_b$ ;
- compare strong and weak acids and bases using the concept of equilibrium;
- describe the characteristics and components of a buffer solution.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate vocabulary to communicate ideas, procedures, and results related to chemical systems and equilibrium (e.g., *homogeneous*, *common ion*,  $K_a$  value);
- apply Le Chatelier's principle to predict how various factors affect a chemical system at equilibrium, and confirm their predictions through experimentation;
- carry out experiments to determine equilibrium constants (e.g.,  $K_{eq}$  for iron [III] thiocyanate,  $K_{sp}$  for calcium hydroxide,  $K_a$  for acetic acid);
- calculate the molar solubility of a pure substance in water or in a solution of a common ion, given the solubility product constant ( $K_{sp}$ ), and vice versa;
- predict the formation of precipitates by using the solubility product constant;
- solve equilibrium problems involving concentrations of reactants and products and the following quantities:  $K_{eq}$ ,  $K_{sp}$ ,  $K_a$ ,  $K_b$ , pH, pOH;
- predict, in qualitative terms, whether a solution of a specific salt will be acidic, basic, or neutral;
- solve problems involving acid-base titration data and the pH at the equivalence point.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- explain how equilibrium principles may be applied to optimize the production of industrial chemicals (e.g., production of sulfuric acid, ammonia);
- identify effects of solubility on biological systems (e.g., kidney stones, dissolved gases in the circulatory system of divers, the use of barium sulfate in medical diagnosis);
- explain how buffering action affects our daily lives, using examples (e.g., the components in blood that help it to maintain a constant pH level; buffered medications).

## Electrochemistry

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of fundamental concepts related to oxidation-reduction and the interconversion of chemical and electrical energy;
- build and explain the functioning of simple galvanic and electrolytic cells; use equations to describe these cells; and solve quantitative problems related to electrolysis;
- describe some uses of batteries and fuel cells; explain the importance of electrochemical technology to the production and protection of metals; and assess environmental and safety issues associated with these technologies.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of oxidation and reduction in terms of the loss and the gain of electrons or change in oxidation number;
- identify and describe the functioning of the components in galvanic and electrolytic cells;
- describe electrochemical cells in terms of oxidation and reduction half-cells whose voltages can be used to determine overall cell potential;
- describe the function of the hydrogen half-cell as a reference in assigning reduction potential values;
- demonstrate an understanding of the inter-relationship of time, current, and the amount of substance produced or consumed in an electrolytic process (Faraday's law);
- explain corrosion as an electrochemical process, and describe corrosion-inhibiting techniques (e.g., painting, galvanizing, cathodic protection).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to electrochemistry (e.g., *half-reaction*, *electrochemical cell*, *reducing agent*, *redox reaction*, *oxidation number*);
- demonstrate oxidation-reduction reactions through experiments, and analyse these reactions (e.g., compare the reactivity of some metals by arranging them in order of their ease of oxidation, which can be determined through observation of their ability to displace other metals from compounds; investigate the reactivity of oxidizing agents such as oxygen and various acids);
- write balanced chemical equations for oxidation-reduction systems, including half-cell reactions;
- determine oxidation and reduction half-cell reactions, direction of current flow, electrode polarity, cell potential, and ion movement in typical galvanic and electrolytic cells, including those assembled in the laboratory;

- predict the spontaneity of redox reactions and overall cell potentials by studying a table of half-cell reduction potentials;
- solve problems based on Faraday's law;
- measure through experimentation the mass of metal deposited by electroplating (e.g., copper from copper II sulfate), and apply Faraday's law to relate the mass of metal deposited to the amount of charge passed.
- explain how electrolytic processes are involved in industrial processes (e.g., refining of metals, production of chlorine);
- research and assess environmental, health, and safety issues involving electrochemistry (e.g., the corrosion of metal structures by oxidizing agents; industrial production of chlorine by electrolysis and its use in the purification of water).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe examples of common galvanic cells (e.g., lead-acid, nickel-cadmium) and evaluate their environmental and social impact (e.g., describe how advances in the hydrogen fuel cell have facilitated the introduction of electric cars);

## Structure and Properties

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of quantum mechanical theory, and explain how types of chemical bonding account for the properties of ionic, molecular, covalent network, and metallic substances;
- investigate and compare the properties of solids and liquids, and use bonding theory to predict the shape of simple molecules;
- describe products and technologies whose development has depended on understanding molecular structure, and technologies that have advanced the knowledge of atomic and molecular theory.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- explain the experimental observations and inferences made by Rutherford and Bohr in developing the planetary model of the hydrogen atom;
- describe the quantum mechanical model of the atom (e.g., orbitals, electron probability density) and the contributions of individuals to this model (e.g., those of Planck, de Broglie, Einstein, Heisenberg, and Schrödinger);
- list characteristics of the *s*, *p*, *d*, and *f* blocks of elements, and explain the relationship between position of elements in the periodic table, their properties, and their electron configurations;
- explain how the properties of a solid or liquid (e.g., hardness, electrical conductivity, surface tension) depend on the nature of the particles present and the types of forces between them (e.g., covalent bonds, Van der Waals forces, dipole forces, and metallic bonds);
- explain how the Valence Shell Electron Pair Repulsion (VSEPR) model can be used to predict molecular shape.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to structure and bonding (e.g., *orbital*, *absorption spectrum*, *quantum*, *photon*, *dipole*);
- write electron configurations for elements in the periodic table, using the Pauli exclusion principle and Hund's rule;
- predict molecular shape for simple molecules and ions, using the VSEPR model;
- predict the polarity of various substances, using molecular shape and the electronegativity values of the elements of the substances;
- predict the type of solid (ionic, molecular, covalent network, or metallic) formed by a substance, and describe its properties;
- conduct experiments to observe and analyse the physical properties of different substances, and to determine the type of bonding present.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- describe some applications of principles relating to atomic and molecular structure in analytical chemistry and medical diagnosis (e.g., infrared spectroscopy, X-ray crystallography, nuclear medicine, medical applications of spectroscopy);
- describe some specialized new materials that have been created on the basis of the findings of research on the structure of matter, chemical bonding, and other properties of matter (e.g., bulletproof fabric, superconductors, superglue);
- describe advances in Canadian research on atomic and molecular theory (e.g., the work of Richard Bader at McMaster University in developing electron-density maps for small molecules; the work of R.J. LeRoy at the University of Waterloo in developing the mathematical technique for determining the radius of molecules called the LeRoy Radius).

## Chemistry, Grade 12, College Preparation

(SCH4C)

This course introduces students to the concepts that form the basis of modern chemistry. Students will study qualitative analysis, quantitative relationships in chemical reactions, organic chemistry and electrochemistry, and chemistry as it relates to the quality of the environment. Students will employ a variety of laboratory techniques, develop skills in data collection and scientific analysis, and communicate scientific information using appropriate terminology. Emphasis will be placed on the role of chemistry in daily life and in the development of new technologies and products.

**Prerequisite:** Science, Grade 10, Academic or Applied

***Throughout this course, students will:***

- demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., safely disposing of organic solutions; correctly interpreting Workplace Hazardous Materials Information System [WHMIS] symbols), and using appropriate personal protection (e.g., wearing safety goggles);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., use equipment such as a spectroscope and centrifuge to conduct qualitative analysis);
- demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., manipulate burettes and other instruments used in an acid/base titration);
- demonstrate a knowledge of emergency laboratory procedures;
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., represent ionic and molecular compounds by their accepted formulae and names);
- select, integrate, and interpret information derived from experiments and from print and electronic sources, including Internet sites, and, either in writing or using a computer, compile and display the information in various forms, including diagrams, tables, graphs, and laboratory reports (e.g., using both experimental results and information from other sources, compile a table summarizing the physical and chemical properties of some common organic compounds);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- select and use appropriate SI units;
- identify and describe science- and technology-based careers related to the subject area under study (e.g., describe careers related to analytical chemistry, such as laboratory technician or quality control officer).

## Matter and Qualitative Analysis

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the basic principles of qualitative analysis and underlying theories;
- carry out qualitative analyses, using flow charts and appropriate laboratory equipment and instruments;
- describe the role and importance in society of some of the applications of qualitative analysis.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- explain the distinction between observation and inference;
- describe and explain basic processes and phenomena involved in qualitative analysis, including flame tests, precipitation reactions, and absorption spectra;
- relate observations from flame tests and absorption spectra to the concept of quanta of energy proposed by Bohr;
- explain covalent bonding in simple molecules using Lewis structures (e.g.,  $\text{H}_2$ ,  $\text{Cl}_2$ ,  $\text{O}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_4$ );
- demonstrate an understanding of the formation of ionic bonds between metals and non-metals, and relate the charge on an ion to the number of electrons lost or gained.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to qualitative analysis (e.g., *double displacement*, *precipitate*, *energy levels*);
- conduct qualitative analyses using equipment and instruments such as the following: gas discharge tubes, high voltage electrical sources, spectroscope, centrifuge;

- predict the precipitate formed in a chemical reaction by writing double displacement and net ionic equations and using a table of solubility rules;
- use a flow chart and experimental procedures, including flame tests and precipitation reactions, to determine the presence of ions in an unknown sample (e.g., analyse a household or workplace chemical);
- identify an unknown gas sample (e.g., hydrogen, helium, neon) by comparing its observed absorption spectrum with those of known gases.

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- describe some applications of spectroscopy (e.g., in astronomy to identify the composition of stars);
- explain applications of qualitative analysis in various fields (e.g., discuss the use of qualitative analysis techniques in drug detection or in the identification of counterfeit money).

## Organic Chemistry

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the names and properties of organic compounds and some of their reactions;
- carry out various laboratory tests and reactions involving organic compounds;
- describe the importance of organic compounds in consumer products, technological devices, and biochemical applications, and explain some of the issues related to their environmental and social impact.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of the particular characteristics of the carbon atom in terms of the type of bonding and the formation of long chains;
  - explain the general properties of molecules containing oxygen or nitrogen (e.g., polarity, solubility in water);
  - identify the functional group structures that define common families (e.g., alkenes, alkynes, alcohols, aldehydes, ketones, acids, esters, amines);
  - describe, using structural formulae, typical organic reactions such as addition, combustion, and addition polymerization reactions;
  - explain the principle underlying the use of distillation to separate organic compounds.
- draw Lewis structures to represent covalent bonding in organic molecules (e.g., methane, ethanol, butene, acetylene);
  - determine through experimentation the physical and chemical properties of some common organic compounds (e.g., aqueous and non-aqueous solubility, combustibility, conductivity, odour), and identify patterns and trends in these observations;
  - identify through experimentation some of the products of the combustion of a hydrocarbon and an alcohol, and write balanced chemical equations to represent the combustion reaction;
  - synthesize a condensation product (e.g., aspirin or an ester), a common organic compound (e.g., soap), and a synthetic polymer (e.g., cross-link polyvinyl alcohol using a solution of borax).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to organic chemistry (e.g., *electronegativity*, *covalent bond*, *functional group*, *polymer*);
- select and use apparatus safely to separate a mixture of liquids by distillation;

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- identify useful organic compounds (e.g., non-stick coatings for cookware) on the basis of information gathered from print and electronic sources, and illustrate their molecular structure and functional groups using representations drawn by hand or by computer;

- describe the role of distillation and cracking in the production of useful fuels from crude oil;
- explain the dangers associated with the use of organic solvents (e.g., combustibility, toxicity) and the necessary precautions to be taken;
- identify issues connected to the growing use of plastics (e.g., the consumption of fossil fuels, waste disposal), and suggest alternative materials that could be used;
- describe how organic chemistry has led to the development of useful new products (e.g., synthetic fabrics, automobile body panels, artificial heart valves).

## Electrochemistry

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the chemical processes that take place in galvanic and electrolytic cells;
- investigate through experimentation the ease of oxidation of metals, and build electrochemical cells and describe their functioning;
- explain the importance for industry and the consequences for the environment of common electrochemical processes.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- name the components of galvanic and electrolytic cells, describe their role, and explain how they function in terms of oxidation and reduction;
- explain the chemical reactions involved in corrosion, and describe their similarity to chemical reactions occurring in an electrochemical cell;
- identify and explain various techniques used to prevent corrosion of metals (e.g., painting, cathodic protection, galvanization).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to electrochemistry (e.g., *ionic bonds, oxidation, anode, electrolyte*);
- use the following laboratory equipment and instruments safely and accurately: voltmeters, electrical sources, connecting wires;

- classify, using experimental evidence, metals, acids, bases, salt solutions, and covalent substances as conductors or non-conductors of electricity;
- interpret observations from experiments to determine an activity series of some metals;
- predict the spontaneity of displacement reactions between metal elements and metal salts based on the activity series, and verify the predictions through experimentation;
- construct a galvanic cell, and determine its advantages and disadvantages (e.g., source of energy, portability, rechargeability; chemical spillage, limited voltage);
- describe an electrochemical cell in terms of half-cell reactions, location of electrodes, direction of electron flow, and direction of migration of ions;
- design and carry out procedures to determine the factors that affect rate of corrosion (e.g., stress, two-metal contacts, surface oxide, nature of electrolyte, nature of metal).

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- describe applications of electrochemical cells, such as batteries;
- explain how electrolytic processes are used in the refining of metals (e.g., Al, Cu, or Ni), and evaluate the impact of such processes on the environment (e.g., production of acid rain, high-energy consumption);
- identify electrochemical processes used in industry (e.g., chrome-plating);
- describe the effects of road salt and acid rain on the process of corrosion, and suggest possible ways of counteracting these effects.

## Chemical Calculations

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the mole concept as well as of quantitative relationships in chemical reactions;
- use techniques of quantitative analysis in the preparation of standard solutions, and solve problems involving the analysis of quantities in chemical reactions, using both theoretical and experimentally measured quantities;
- explain the importance of quantitative chemical relationships in industry and in everyday life.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define the mole concept and demonstrate an understanding of its usefulness in the analysis of quantities involved in chemical reactions (e.g., explain how the mole concept allows the calculation of the number of atoms, ions, or molecules in a quantity of substance);
  - explain how the following variables are related: coefficients in balanced chemical equations, quantity in moles, mass, and number of particles;
  - identify sources of experimental error that would explain a percentage yield other than 100 per cent.
- calculate the molecular mass and molar mass of a compound with the aid of the periodic table;
  - calculate percentage composition of a compound using experimental data or its chemical formula;
  - solve problems involving relationships among the following variables: quantity in moles, mass, number of particles, concentration, volume of solution;
  - solve problems involving stoichiometric relationships in balanced chemical equations;
  - calculate percentage yield in a chemical reaction using experimental data, and identify sources of error;

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to stoichiometry (e.g., *molar mass*, *molarity*, *percentage yield*, *Avogadro's number*);
- conduct quantitative analyses, using correctly and accurately the following instruments: pipette, burette, volumetric flask, spectrophotometer, electronic balance;
- prepare aqueous solutions, using appropriate concentration units (e.g., grams per litre, moles per litre), and accurately dilute a stock solution to a specified lower concentration;
- prepare standard solutions and measure their absorbance in order to produce an experimental calibration curve.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- give examples of everyday situations in which an understanding of quantitative relationships of substances is important (e.g., in making decisions about quantities in cooking recipes, in determining dosages in medical prescriptions);
- explain why it is important to ensure accuracy in the concentration of certain solutions (e.g., cough syrup, intravenous solutions);
- explain why the profitability of an industry (e.g., the pharmaceutical industry) depends in large part on its ability to maximize percentage yield of its products.

## Chemistry in the Environment

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the nature and role of elements and compounds in the environment, including acids and bases, and gases in the atmosphere;
- use the techniques involved in the quantitative analysis of solutions effectively and accurately;
- assess the effects and the implications for society of the levels of various substances in the environment, and demonstrate an awareness of the need for both government and individual citizens to take measures that will ensure a healthy environment.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- explain in qualitative terms the effect of temperature and pressure on the volume of a fixed quantity of gas;
- state and explain the Arrhenius definition of acids and bases;
- explain the difference between strong and weak acids and bases in terms of degree of dissociation (e.g., as measured using solution conductivity);
- identify the gases responsible for acid rain, and describe their sources, the steps in acid-rain formation, and the chemical methods used to reverse the process (e.g., neutralization);
- demonstrate an understanding of the precise meaning of the terms *concentrated* and *dilute* when applied to acids (the terms do not indicate the reactivity of the acid – e.g., acetic acid, which is a weak acid, can be purchased in a concentrated form as glacial acetic acid), and explain the safety procedures that must be followed in diluting concentrated acids;
- identify substances in environmental water (including ions that contribute to hardness) whose concentration must be measured and controlled to ensure that the water is fit for human use;

- identify gases in the atmosphere that affect air quality (e.g., greenhouse gases, tropospheric and stratospheric ozone, carbon monoxide, chlorofluorocarbons).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate scientific vocabulary to communicate ideas related to chemical analysis (e.g., *ozone*, *hard water*, *titration*, *pH value*);
- use the following instruments correctly and accurately: electronic balance, burette, pH meter;
- demonstrate through experimentation the acid-base character of solutions of oxides of metals and non-metals, and compare these solutions to the substances present in acid rain;
- write balanced chemical equations to represent neutralization of acids and bases;
- conduct an acid-base titration to determine the concentration of an acid or a base (e.g., acetic acid in vinegar);
- determine the concentration of dissolved ions (e.g., calcium ions) in a water sample, using gravimetric and colorimetric analysis.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- demonstrate an awareness of how governmental regulations (e.g., the Great Lakes Action Plan) as well as the actions of individual people can improve air and water quality (e.g., discuss how individuals can contribute to the improvement of air quality through their choice of transportation);
- assess the environmental, economic, and societal implications of methods of use and disposal of common household products (e.g., analyse the issues involved in the use and disposal in everyday life of detergents containing phosphates, or of batteries and cleaners containing acids and bases);
- explain the importance of quantitative analysis of substances in air and water samples (e.g., explain how measuring levels of dissolved oxygen in samples of lake or river water is important in monitoring the health and use of the surrounding ecosystem).

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# Earth and Space Science

## Earth and Space Science, Grade 12, University Preparation

(SES4U)

This course focuses on the Earth as a planet, and on the basic concepts and theories of Earth science and their relevance to everyday life. Students will examine the Earth's place in the solar system and, after a general introduction to Earth science, will explore in more detail the materials of the Earth, its internal and surficial processes, and its history. The course draws on astronomy, biology, chemistry, mathematics, and physics in its consideration of geological processes that can be observed directly or inferred from other evidence.

**Prerequisite:** Science, Grade 10, Academic

***Throughout this course, students will:***

- demonstrate an understanding of Workplace Hazardous Materials Information System (WHMIS) legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., following safety procedures when sampling rocks; using materials safely when identifying minerals and rocks), and by using appropriate personal protection (e.g., wearing safety glasses when sampling, and hard hats when visiting outcrops and quarries);
- select appropriate instruments and use them safely, effectively, and accurately in collecting observations and data (e.g., hand lens, polarizing microscope);
- use safe procedures to protect the eyes when observing the sky by day, and choose safe, secure locations when observing the sky at night;
- demonstrate an understanding of emergency laboratory procedures;
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., use an appropriate time scale when representing geological time, or appropriate units to represent astronomical distances);
- select, integrate, and analyse information from print and electronic sources, including Internet sites, and, either in writing or using a computer, compile and display the information in various forms, including flow charts, tables, and graphs (e.g., use the Internet to compile information on areas of major earthquake activity, and compare the frequency and intensity of the activity in graphical form);
- communicate the procedures and results of investigations and research for specific purposes using data tables and laboratory reports (e.g., prepare a table of known and unknown minerals sorted in groups according to physical properties such as hardness, colour, and streak);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- select and use appropriate SI units (units of measurement of the *Système international d'unités*, or International System of Units);
- identify and describe careers related to Earth and space science (e.g., careers related to hydrology, meteorology, geology, mineralogy, astronomy, and remote sensing).

## The Earth As a Planet

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the properties of the Earth and of the internal (geological) and external (cosmic) processes operating on it, and draw comparisons with other objects in the solar system;
- investigate and analyse the Earth's place in the solar system and the effects of cosmic and geological processes on it and on other objects in the solar system;
- describe and explain how observations of the Earth and other objects in the solar system, made both from Earth and from space, are used to study and better understand the natural and the human-made environments of the Earth.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- visualize and describe the size, shape, and motions of the solar system, and the place of the Earth within it;
- describe the origin and evolution of the Earth and other objects in the solar system, and identify the fundamental forces and processes involved;
- compare the Earth with other objects in the solar system with respect to such properties as mass, size, composition, rotation, and magnetic field;
- describe and explain the following external processes and phenomena that affect the Earth: radiation and particles from the “quiet” and “active” sun; gravity and tides of the sun and moon; and the impacts of asteroidal and cometary material;
- describe the properties of the near-Earth space environment.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- formulate scientific questions about the nature, origin, and evolution of the Earth and other objects in the solar system;
- visualize and describe the size, shape, and motions of the solar system, and compare the Earth with other planets and objects within it, on the basis of information gathered through research;
- assess critically the scientific questions they have formulated and the information they have gathered in order to identify the fundamental forces and processes that shape the interior, surface, and atmosphere of the Earth and other objects in the solar system;
- identify surface features of the Earth and other objects in the solar system (e.g., craters, faults, volcanoes), using light, infrared, and radio/radar images;
- investigate, either through laboratory activities or research, the interaction of radiation and impacting particles with Earth materials such as air, water, and rock;
- assess the risks associated with solar ultraviolet radiation, and with the collision of asteroidal and cometary material with the Earth.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- explain how the study of other planets and objects in the solar system has led to a better understanding of the Earth (e.g., explain how studying the greenhouse effect on Venus has increased understanding of the same effect on Earth);
- demonstrate an understanding of some of the historical, cultural, and aesthetic consequences of changes in the perception and understanding of the Earth's place in space (e.g., evaluate the impact of images of the whole Earth taken from space);
- describe how observations and measurements of the Earth made from space are used to study and better understand natural physical elements of the Earth's environment (e.g., its crust, water, air) as well as human-made elements (e.g., crops, cities, air and water pollution);
- describe the challenges of designing piloted and robotic spacecraft, and of operating them in near-Earth space;
- investigate Canada's contributions to the study of our planet from near-Earth space (e.g., Radarsat, International Space Station), using information from various print and electronic sources;
- evaluate the negative effects of human activity on near-Earth space (e.g., space debris, pollution of the electromagnetic spectrum).

## Introduction to Earth Sciences

### Overall Expectations

By the end of this course, students will:

- identify and describe the elements and dynamic interactions of the Earth's natural systems;
- investigate the basic structure of the planet and the geological processes associated with it, and use the knowledge gained to explain the major interactions among the hydrosphere, lithosphere, biosphere, and atmosphere;
- assess the impact of natural forces and systems on the Earth's physical and human environments, as well as the impact of human activities on natural systems.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of the range of physical scales that apply in the Earth sciences (e.g., from those that apply to the planet as a whole to those used at the atomic level);
- describe the major interactions among the four spheres of the Earth – the atmosphere, hydrosphere, lithosphere, and biosphere;
- demonstrate an understanding of the continuous recycling of major rock types throughout Earth history, of the evidence that this process provides with respect to the length and complexity of Earth history, and of the very late appearance of human beings in the geological record;
- describe various kinds of evidence that suggests that life forms, climate, continental positions, and the Earth's crust have changed over time (e.g., the extinction of the dinosaurs, evidence of past glaciations, evidence of the existence of Pangaea and Gondwanaland).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- interpret data about the nature of natural disasters, and explain the involvement of physical processes and the role of Earth science in connection with such events;
- demonstrate an understanding of the major tools and techniques (e.g., seismograph, magnetic signature of the ocean floor) that various Earth scientists (e.g., seismologists, geophysicists) use to conduct research on the basic structure and processes of the planet;
- document and explain, through investigation, examples of the complex interconnectedness of physical, chemical, and biological processes as they apply to the Earth (e.g., plants live in the biosphere by taking nutrients and other crucial substances from the other three spheres of the Earth, to which they also contribute important substances).

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- explain the interactions of the atmosphere and hydrosphere in the water cycle, and the impact of these interactions on humans;
- describe and explain the effects of natural systems on the Earth's physical and human environments, and the increasing alteration of certain natural systems that has resulted from human activities;
- analyse, through cooperative research, national and international Earth science endeavours (e.g., Lithoprobe, Ocean Drilling Program) that have increased our understanding of the Earth's crust, and assess the merits of funding such projects;
- assess how developments in technology have contributed to our understanding of the Earth (e.g., the development of sonar to map the ocean floor).

## Earth Materials

### Overall Expectations

By the end of this course, students will:

- distinguish between minerals and rocks, and describe the formation and characteristics of both;
- apply a series of specific tests to identify minerals and rocks, including those in the local area, and to determine their physical properties;
- demonstrate an understanding of society's dependence on Earth materials, of the effects of developments in technology on the exploration and mining of Earth materials, and of the ways in which the use and extraction of Earth materials have affected natural and human-made environments.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- identify different minerals by their physical and chemical properties, and demonstrate understanding that minerals are the constituents of rocks;
- describe the formation of igneous rocks (plutonic and volcanic), and identify their distinguishing characteristics (e.g., composition and flow behaviour; characteristics of volcanic rocks that indicate the type of volcano in which they were formed);
- describe the formation of clastic and chemical sediments, and of the corresponding sedimentary rocks;
- describe the different ways in which metamorphic rocks are formed (i.e., through changes in temperature, pressure, and chemical conditions) and the factors that contribute to their variety (e.g., variation in parent rock);
- explain (e.g., by interpreting a rock cycle diagram) how rocks and their constituent minerals are continuously being recycled.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- apply a series of tests (e.g., tests evaluating hardness, streak, and density) to identify common minerals (e.g., quartz, calcite, potassium feldspar, plagioclase feldspar, muscovite, biotite, talc, graphite, gold, silver);
- identify and classify selected hand samples of unknown minerals on the basis of their physical properties (e.g., sort the groups by hardness, colour, streak);
- apply a series of tests to identify common igneous rocks (e.g., granite, obsidian, andesite, basalt, gabbro, peridotite), and classify each according to its origin (e.g., volcanic, plutonic), texture (e.g., coarse- or fine-grained, vesicular, glassy), and composition (e.g., mafic, felsic, intermediate);
- apply a series of tests to identify sedimentary rocks (e.g., conglomerate, breccia, sandstone, shale, limestone, chert, gypsum, rock salt, coal), and classify each according to its origin (e.g., clastic, chemical), texture (e.g., coarse- or fine-grained, detrital), and composition;

- apply a series of tests to identify and classify metamorphic rocks (e.g., slate, phyllite, schist, gneiss, quartzite, marble) and, on the basis of the characteristics of each type, identify its parent rock and the temperature, pressure, and chemical conditions at its formation;
  - investigate and describe the geological setting of the local area (e.g., examine the geological setting of a local river/stream bed or lakeshore, and identify and classify rock types on the basis of representative samples collected at the site).
- Relating Science to Technology, Society, and the Environment***
- By the end of this course, students will:
- explain the importance of minerals and other Earth resources (e.g., sand, gravel, dimension stone, oil and gas), and of exploration for these resources, for the local, provincial, and national economies;
  - describe and assess the role of Earth materials in the safe disposal of industrial and urban waste and toxic materials;
  - describe the uses and evaluate the economic importance of minerals, rocks, and metallic resources (e.g., gold, silver, nickel, copper) and non-metallic resources (e.g., sand and gravel, aggregates, oil and gas, lime, gypsum, industrial minerals, gems);
  - describe the use of dimension stone (e.g., in buildings and cemeteries) and explain how the development of new technologies has influenced the type of stone used in the local area (e.g., relate advances in the technology for quarrying and cutting stone to changes in the type of stone used);
  - describe some of the technologies used to recover natural resources from the Earth, and evaluate economic, social, and environmental ramifications of their use (e.g., the need for fewer workers and the practice of site rehabilitation resulting from the use of improved technologies in the mining of nickel).

## Internal and Surficial Earth Processes

### Overall Expectations

By the end of this course, students will:

- identify the processes at work within the Earth (e.g., plate tectonics, earthquakes, volcanism) and on its surface (e.g., running water, weathering and erosion, mass wasting, glaciation), and describe the role of both types of processes in shaping the Earth's surface;
- investigate, through the use of models and analysis of information gathered from various sources, the nature of internal and surficial Earth processes, and the ways in which these processes can be measured;
- demonstrate an understanding of the interrelationships between internal and surficial Earth processes (e.g., earthquake activity, volcanic eruptions, floods, erosion) and the ways in which they affect human activity.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of the kinds of evidence that Earth scientists use to document lithospheric plate motion (e.g., the corresponding shapes of the coastlines of Africa and South America; fossil evidence);
- distinguish between faults and joints;
- describe the characteristics of the three main types of seismic waves, P-, S-, and L-waves, and explain the different modes of travel, travel times, and types of motion associated with each;
- distinguish between erosion and weathering, and describe the processes and effects of physical, chemical, and biological weathering;
- demonstrate an understanding of the importance of different erosional processes, and describe the types and causes of mass wasting (e.g., landslides) and its critical role in changing the Canadian landscape;
- identify types of sediment transport (e.g., wind, water, glacial), and compare the particle size and shape, degree of sorting, and sedimentary structures resulting from each;

- identify the types of stream load (i.e., solution, suspension, and bedload) and describe how each moves in a stream;
- demonstrate an understanding of the importance of aquifers and of their fragility in terms of contamination and depletion.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- describe, on the basis of information gathered from print and electronic sources, the various types of possible margins between lithospheric plates (e.g., convergent, divergent, transform, and intraplate activity) and the types of internal Earth processes occurring at each;
- produce diagrams of the following structures, and identify examples of them in maps and photographs: normal, reverse, thrust, and strike-slip (transform) faults; domes and basins; anticlines and synclines;
- investigate and produce a model of each type of seismic wave, using springs and ropes, and describe for each the nature of its propagation and the resulting movement within the rocks through which it is travelling;

- compare qualitative and quantitative methods (e.g., the Mercalli Scale and the Richter Scale) used to measure earthquake intensity and magnitude;
- produce a diagram or model, to scale, of the interior of the Earth in order to differentiate among the layers of the Earth and their characteristics (e.g., use cross-sections to provide the dimensions of crust, mantle, and inner and outer core, and travel-time curves for various seismic waves to provide data on the characteristics of the individual layers);
- design and construct a working model of a seismograph, and explain its use in recording earthquake activity;
- locate the epicentre of an earthquake, given the appropriate seismographic data (e.g., the travel-time curves to three recording stations for a single event);
- design and test methods to control mass wasting;
- relate the characteristics of sediment (e.g., grain size, shape, composition) to the velocity and direction of currents in a beach or stream environment (e.g., examine where sediment is being eroded and deposited in a local beach or river/stream environment);
- investigate and explain the interrelationship among geological maps, cross-sections, and block diagrams, and the ways in which they represent the subsurface structure and/or the geological history of an area.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe methods of monitoring and predicting earthquakes, tsunamis, and volcanic eruptions;
- describe and explain how the development of the seismograph has contributed to a better understanding of the internal structure of the Earth;
- identify and describe engineering and technological innovations and adaptations resulting from human activity in areas of permafrost (e.g., pipeline construction, oil and natural gas exploration, residential construction and urbanization);
- identify and describe engineering and technological innovations and adaptations (e.g., in building design, highway construction, emergency services) resulting from the impact of earthquake activity on human populations;
- describe the underlying assumptions and the limitations of predictions of earthquake activity, and assess the implications of such predictions for populations in Canada and around the world;
- identify major areas of tectonic activity in the world (e.g., Japan – convergent margin; Iceland – divergent margin; California – transform fault), drawing on information about the relationship between earthquakes, volcanoes, and plate boundaries (e.g., plot on a world map, for a given time period, the locations of recorded earthquakes and active volcanoes);
- demonstrate an understanding of how erosion and deposition by streams are affected by load, gradient, channel shape, sediment composition, and human activities.

## Earth History

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the concept of geological time;
- analyse and assess geological evidence that suggests that life forms, climate, continental positions, and the Earth's crust have changed over time;
- explain the importance of the geological and fossil records for our understanding of the Earth's history, and describe their use in related economic activities.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of the differences between relative and absolute dating techniques as they apply to natural systems;
- describe and explain the various methods of isotopic age determination, giving for each the name of the isotope, its half-life, its effective dating range, and some of the materials (e.g., minerals and rocks) that it can be used to date;
- describe some processes by which fossils are produced and/or preserved (e.g., original preservation, carbonization, replacement, permineralization, and mould and cast formations), and sketch a representative fossil of a foraminifer, mollusc, brachiopod, echinoderm, arthropod, coelenterate, vertebrate, graptolite, and plant;
- describe the diversity of life in the Proterozoic, Paleozoic, Mesozoic, and Cenozoic eras and the ranges of important groups of fossils that date from each.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use and interpret information from appropriate sources (e.g., a sequence diagram, geological maps showing major geological regions and associated rock types) in describing the geological history of an area (e.g., Ontario);
- investigate and analyse various types of preserved geological evidence of changes that have taken place in Earth history (e.g., past glaciations, tectonic activity, plate movement);
- demonstrate an understanding of the evolution of life, as revealed through fossil analysis;
- demonstrate the ability to use the geological time scale as an aid in interpreting the history of a sequence of strata;
- investigate and interpret the significance of an unconformity preserved in a sequence of strata (e.g., the boundary between Paleozoic and Precambrian rocks in southern Ontario);
- investigate radioactive decay and the concept of half-life determination (e.g., design a simple, safe experiment that provides a model of half-life decay of radioactive elements);

- analyse the evidence used to determine the age of the Earth (e.g., radiometric dating of geological materials), and outline the historical evolution of attempts to establish the Earth's chronology.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- illustrate the geological time scale and compare it to human time scales (e.g., develop a series of timelines to represent their life, their family tree or history, the history of Canada, the history of civilization, the geological history of the local area, and the major events in Earth history, and compare the scales necessary to present this data on a 1m strip);
- demonstrate an understanding of the significance of paradigm shifts in the development of geological thinking (e.g., contrast the principles of uniformitarianism and catastrophism);
- demonstrate an understanding of the importance of fossils in the petroleum and mining industries as tools for biostratigraphic correlation and as indicators of depositional environments;
- describe Canadian contributions to our knowledge about absolute age dating and to technological applications based on this knowledge.

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# Physics

## Physics, Grade 11, University Preparation

(SPH3U)

This course develops students' understanding of the basic concepts of physics. Students will study the laws of dynamics and explore different kinds of forces, the quantification and forms of energy (mechanical, sound, light, thermal, and electrical), and the way energy is transformed and transmitted. They will develop scientific-inquiry skills as they verify accepted laws and solve both assigned problems and those emerging from their investigations. Students will also analyse the interrelationships between physics and technology, and consider the impact of technological applications of physics on society and the environment.

**Prerequisite:** Science, Grade 10, Academic

***Throughout this course, students will:***

- demonstrate an understanding of safety practices by selecting, operating, and storing equipment appropriately, and by acting in accordance with the Workplace Hazardous Materials Information System (WHMIS) legislation in selecting and applying techniques for handling, storing, and disposing of laboratory materials (e.g., check all electrical equipment for damage prior to conducting an experiment);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., collect data accurately using stopwatches, photogates, or data loggers);
- demonstrate the skills required to design and carry out experiments related to the topics under study, controlling major variables and adapting or extending procedures where required (e.g., investigate the relationships among force, mass, and acceleration);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., interpret data, using graphs and graphical analysis techniques; explain, using a ray diagram, the operation of an optical instrument);
- use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena (e.g., use the kinetic molecular theory of matter to explain thermal energy and its transfer [heat]); use ray diagrams to predict the location and nature of images created by lenses);
- analyse and synthesize information for the purpose of identifying problems for inquiry, and solve the problems using a variety of problem-solving skills;
- select and use appropriate SI units (units of measurement of the *Système international d'unités*, or International System of Units), and apply unit analysis techniques when solving problems;

- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation (e.g., algebraic equations, vector diagrams, ray diagrams, graphs, graphing programs, spreadsheets) to communicate scientific ideas, plans, and experimental results;
- communicate the procedures and results of investigations and research for specific purposes using data tables, laboratory reports, and research papers, and account for discrepancies between theoretical and experimental values with reference to experimental uncertainty;
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- identify and describe science- and technology-based careers related to the subject area under study (e.g., electrical engineer, computer technologist).

## Forces and Motion

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the relationship between forces and the acceleration of an object in linear motion;
- investigate, through experimentation, the effect of a net force on the linear motion of an object, and analyse the effect in quantitative terms, using graphs, free-body diagrams, and vector diagrams;
- describe the contributions of Galileo and Newton to the understanding of dynamics; evaluate and describe technological advances related to motion; and identify the effects of societal influences on transportation and safety issues.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe concepts and units related to force and motion (e.g., vectors, scalars, displacement, uniform motion, instantaneous and average velocity, uniform acceleration, instantaneous and average acceleration, applied force, net force, static friction, kinetic friction, coefficients of friction);
- describe and explain different kinds of motion, and apply quantitatively the relationships among displacement, velocity, and acceleration in specific contexts;
- analyse uniform motion in the horizontal plane in a variety of situations, using vector diagrams;
- identify and describe the fundamental forces of nature;
- analyse and describe the gravitational force acting on an object near, and at a distance from, the surface of the Earth;
- analyse and describe the forces acting on an object, using free-body diagrams, and determine the acceleration of the object;
- state Newton's laws, and apply them to explain the motion of objects in a variety of contexts;

- analyse in quantitative terms, using Newton's laws, the relationships among the net force acting on an object, its mass, and its acceleration.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- design and carry out an experiment to identify specific variables that affect motion (e.g., conduct an experiment to determine the factors that affect the motion of an object sliding along a surface);
- carry out experiments to verify Newton's second law of motion;
- interpret patterns and trends in data by means of graphs drawn by hand or by computer, and infer or calculate linear and non-linear relationships among variables (e.g., analyse and explain the motion of objects, using displacement-time graphs, velocity-time graphs, and acceleration-time graphs);
- analyse the motion of objects, using vector diagrams, free-body diagrams, uniform acceleration equations, and Newton's laws of motion.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- explain how the contributions of Galileo and Newton revolutionized the scientific thinking of their time and provided the foundation for understanding the relationship between motion and force;
- evaluate the design of technological solutions to transportation needs and, using scientific principles, explain the way they function (e.g., evaluate the design, and explain the operation of, airbags in cars, tread patterns on car tires, or braking systems);
- analyse and explain the relationship between an understanding of forces and motion and an understanding of political, economic, environmental, and safety issues in the development and use of transportation technologies (including terrestrial and space vehicles) and recreation and sports equipment.

# Energy, Work, and Power

## Overall Expectations

By the end of this course, students will:

- demonstrate an understanding, in qualitative and quantitative terms, of the concepts of work, energy (kinetic energy, gravitational potential energy, and thermal energy and its transfer [heat]), energy transformations, efficiency, and power;
- design and carry out experiments and solve problems involving energy transformations and the law of conservation of energy;
- analyse the costs and benefits of various energy sources and energy-transformation technologies that are used around the world, and explain how the application of scientific principles related to mechanical energy has led to the enhancement of sports and recreational activities.

## Specific Expectations

### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to energy, work, and power (e.g., energy, work, power, gravitational potential energy, kinetic energy, thermal energy and its transfer [heat], efficiency);
- identify conditions required for work to be done, and apply quantitatively the relationships among work, force, and displacement along the line of the force;
- analyse, in qualitative and quantitative terms, simple situations involving work, gravitational potential energy, kinetic energy, and thermal energy and its transfer (heat), using the law of conservation of energy;
- apply quantitatively the relationships among power, energy, and time in a variety of contexts;
- analyse, in quantitative terms, the relationships among per-cent efficiency, input energy, and useful output energy for several energy transformations.

### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- design and carry out experiments related to energy transformations, identifying and controlling major variables (e.g., design and carry out an experiment to identify the energy transformations of a swinging pendulum, and to verify the law of conservation of energy; design and carry out an experiment to determine the power produced by a student);
- analyse and interpret experimental data or computer simulations involving work, gravitational potential energy, kinetic energy, thermal energy and its transfer (heat), and the efficiency of the energy transformation (e.g., experimental data on the motion of a swinging pendulum or a falling or sliding mass in terms of the energy transformations that occur);
- communicate the procedures, data, and conclusions of investigations involving work, mechanical energy, power, thermal energy and its transfer (heat), and the law of conservation of energy, using appropriate means (e.g., oral and written descriptions, numerical and/or graphical analyses, tables, diagrams).

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- analyse, using their own or given criteria, the economic, social, and environmental impact of various energy sources (e.g., wind, tidal flow, falling water, the sun, thermal energy and its transfer [heat]) and energy-transformation technologies (e.g., hydroelectric power plants and energy transformations produced by other renewable sources, fossil fuel, and nuclear power plants) used around the world;
- analyse and explain improvements in sports performance, using principles and concepts related to work, kinetic and potential energy, and the law of conservation of energy (e.g., explain the importance of the initial kinetic energy of a pole vaulter or high jumper).

## Waves and Sound

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the properties of mechanical waves and sound and the principles underlying the production, transmission, interaction, and reception of mechanical waves and sound;
- investigate the properties of mechanical waves and sound through experiments or simulations, and compare predicted results with actual results;
- describe and explain ways in which mechanical waves and sound are produced in nature, and evaluate the contributions to entertainment, health, and safety of technologies that make use of mechanical waves and sound.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to mechanical waves (e.g., longitudinal wave, transverse wave, cycle, period, frequency, amplitude, phase, wavelength, velocity, superposition, constructive and destructive interference, standing waves, resonance);
- describe and illustrate the properties of transverse and longitudinal waves in different media, and analyse the velocity of waves travelling in those media in quantitative terms;
- compare the speed of sound in different media, and describe the effect of temperature on the speed of sound;
- explain and graphically illustrate the principle of superposition, and identify examples of constructive and destructive interference;
- analyse the components of resonance and identify the conditions required for resonance to occur in vibrating objects and in various media;
- identify the properties of standing waves and, for both mechanical and sound waves, explain the conditions required for standing waves to occur;
- explain the Doppler effect, and predict in qualitative terms the frequency change that will occur in a variety of conditions;
- analyse, in quantitative terms, the conditions needed for resonance in air columns, and explain how resonance is used in a variety of situations (e.g., analyse resonance conditions in air columns in quantitative terms, identify musical instruments using such air columns, and explain how different notes are produced).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- draw, measure, analyse, and interpret the properties of waves (e.g., reflection, diffraction, and interference, including interference that results in standing waves) during their transmission in a medium and from one medium to another, and during their interaction with matter;
- design and conduct an experiment to determine the speed of waves in a medium, compare theoretical and empirical values, and account for discrepancies;

- analyse, through experimentation, the conditions required to produce resonance in vibrating objects and/or in air columns (e.g., in string instruments, tuning forks, wind instruments), predict the conditions required to produce resonance in specific cases, and determine whether the predictions are correct through experimentation.
- evaluate the effectiveness of a technological device related to human perception of sound (e.g., hearing aid, earphones, cell phone), using given criteria;
- identify sources of noise in different environments (e.g., traffic noise in neighbourhoods adjacent to highways), and explain how such noise can be reduced to acceptable levels (e.g., noise can be reduced by the erection of highway noise barriers or the use of protective headphones).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe how knowledge of the properties of waves is applied in the design of buildings (e.g., with respect to acoustics) and of various technological devices (e.g., musical instruments, audio-visual and home entertainment equipment), as well as in explanations of how sounds are produced and transmitted in nature, and how they interact with matter in nature (e.g., how organisms produce or receive infrasonic, audible, and ultrasonic sounds);

## Light and Geometric Optics

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the properties of light and the principles underlying the transmission of light through a medium and from one medium to another;
- investigate the properties of light through experimentation, and illustrate and predict the behaviour of light through the use of ray diagrams and algebraic equations;
- evaluate the contributions to such areas as entertainment, communications, and health made by the development of optical devices and other technologies designed to make use of light.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe concepts and units related to light (e.g., reflection, refraction, partial reflection and refraction, index of refraction, total internal reflection, critical angle, focal point, image);
- describe the scientific model for light and use it to explain optical effects that occur as natural phenomena (e.g., apparent depth, shimmering, mirage, rainbow);
- predict, in qualitative and quantitative terms, the refraction of light as it passes from one medium to another, using Snell's law;
- explain the conditions required for total internal reflection, using light-ray diagrams, and analyse and describe situations in which these conditions occur;
- describe and explain, with the aid of light-ray diagrams, the characteristics and positions of the images formed by lenses;
- describe the effects of converging and diverging lenses on light, and explain why each type of lens is used in specific optical devices;
- analyse, in quantitative terms, the characteristics and positions of images formed by lenses.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- demonstrate and illustrate, using light-ray diagrams, the refraction, partial refraction and reflection, critical angle, and total internal reflection of light at the interface of a variety of media;
- carry out an experiment to verify Snell's law;
- predict, using ray diagrams and algebraic equations, the image position and characteristics of a converging lens, and verify the predictions through experimentation;
- carry out experiments involving the transmission of light, compare theoretical predictions and empirical evidence, and account for discrepancies (e.g., given the index of refraction, predict and verify the critical angle of incidence of a substance; given the focal length of a lens, predict and verify the position and characteristics of an image);
- construct, test, and refine a prototype of an optical device (e.g., construct at least one of the following: telescope, microscope, binoculars, periscope, device producing a mirage or a shimmering effect).

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- describe how images are produced and reproduced for the purposes of entertainment and culture (e.g., in movie theatres, in audio-visual and home entertainment equipment, in optical illusions);
- evaluate, using given criteria, the effectiveness of a technological device or procedure related to human perception of light (e.g., eyeglasses, contact lenses, virtual reality “glasses”, infra-red or low light vision sensors, laser surgery);
- analyse, describe, and explain optical effects that are produced by technological devices (e.g., periscopes, binoculars, optical fibres, retro-reflectors, cameras, telescopes, microscopes, overhead projectors).

## Electricity and Magnetism

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the properties, physical quantities, principles, and laws related to electricity, magnetic fields, and electromagnetic induction;
- carry out experiments or simulations, and construct a prototype device, to demonstrate characteristic properties of magnetic fields and electromagnetic induction;
- identify and describe examples of domestic and industrial technologies that were developed on the basis of the scientific understanding of magnetic fields.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to electricity and magnetism (e.g., electric charge, electric current, electric potential, electron flow, magnetic field, electromagnetic induction, energy, power, kilowatt-hour);
- describe the two conventions used to denote the direction of movement of electric charge in an electric circuit (i.e., electric current [movement of positive charge] and electron flow [movement of negative charge]), recognizing that electric current is the preferred convention;
- describe the properties, including the three-dimensional nature, of magnetic fields;
- describe and illustrate the magnetic field produced by an electric current in a long straight conductor and in a solenoid;
- analyse and predict, by applying the right-hand rule, the direction of the magnetic field produced when electric current flows through a long straight conductor and through a solenoid;
- state the motor principle, explain the factors that affect the force on a current-carrying conductor in a magnetic field, and, using the right-hand rule, illustrate the resulting motion of the conductor;
- analyse and describe electromagnetic induction in qualitative terms, and apply Lenz's law to explain, predict, and illustrate the direction of the electric current induced by a changing magnetic field, using the right-hand rule;
- compare direct current (DC) and alternating current (AC) in qualitative terms, and explain the importance of alternating current in the transmission of electrical energy;
- explain, in terms of the interaction of electricity and magnetism, and analyse in quantitative terms, the operation of transformers (e.g., describe the basic parts and the operation of step-up and step-down transformers; solve problems involving energy, power, potential difference, current, and the number of turns in the primary and secondary coils of a transformer).

***Developing Skills of Inquiry and Communication***

By the end of this course, students will:

- conduct an experiment to identify the properties of magnetic fields (e.g., use magnetic compasses and iron filings to identify the properties of magnetic fields), and describe the properties that they find;
- interpret and illustrate, on the basis of experimental data, the magnetic field produced by a current flowing in a long straight conductor and in a coil;
- conduct an experiment to identify the factors that affect the magnitude and direction of the electric current induced by a changing magnetic field;
- construct, test, and refine a prototype of a device that operates using the principles of electromagnetism (e.g., construct an operating prototype of one of the following devices: electric bell, loudspeaker, ammeter, electric motor, electric generator).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- analyse and describe the operation of industrial and domestic technological systems based on principles related to magnetic fields (e.g., electric motors, electric generators, components in home entertainment systems, computers, doorbells, telephones, credit cards);
- describe the historical development of technologies related to magnetic fields (e.g., electric motors and generators, cathode ray [TV] tubes, medical equipment, loudspeakers, magnetic information storage).

## Physics, Grade 12, University Preparation

(SPH4U)

This course enables students to deepen their understanding of the concepts and theories of physics. Students will explore further the laws of dynamics and energy transformations, and will investigate electrical, gravitational, and magnetic fields; electromagnetic radiation; and the interface between energy and matter. They will further develop inquiry skills, learning, for example, how the interpretation of experimental data can provide indirect evidence to support the development of a scientific model. Students will also consider the impact on society and the environment of technological applications of physics.

**Prerequisite:** Physics, Grade 11, University Preparation

***Throughout this course, students will:***

- demonstrate an understanding of safety practices by selecting, operating, and storing equipment appropriately, and by acting in accordance with the Workplace Hazardous Materials Information System (WHMIS) legislation in selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., wear appropriate protective clothing when handling radioactive substances);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., select appropriate instruments, such as stopwatches, photogates, and/or data loggers, when preparing an investigation concerning the law of conservation of energy);
- demonstrate the skills required to design and carry out experiments related to the topics under study, controlling major variables and adapting or extending procedures where required (e.g., design an experiment to determine the relationship between the force applied to a spring and the extension produced);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., analyse the forces acting on an object, using free-body diagrams);
- use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena;
- analyse and synthesize information for the purpose of identifying problems for inquiry, and solve the problems using a variety of problem-solving skills;
- select and use appropriate SI units, and apply unit analysis techniques when solving problems;
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation (e.g., algebraic equations, vector diagrams, ray diagrams, graphs, graphing programs, spreadsheets) to communicate scientific ideas, plans, and experimental results;

- communicate the procedures and results of investigations and research for specific purposes using data tables, laboratory reports, and research papers, and account for discrepancies between theoretical and experimental values with reference to experimental uncertainty;
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- identify and describe science- and technology-based careers related to the subject area under study (e.g., mechanical engineer, civil engineer, medical doctor, astronomer, air-traffic controller, nuclear physicist).

## Forces and Motion: Dynamics

### Overall Expectations

By the end of this course, students will:

- analyse the motion of objects in horizontal, vertical, and inclined planes, and predict and explain the motion with reference to the forces acting on the objects;
- investigate motion in a plane, through experiments or simulations, and analyse and solve problems involving the forces acting on an object in linear, projectile, and circular motion, with the aid of vectors, graphs, and free-body diagrams;
- analyse ways in which an understanding of the dynamics of motion relates to the development and use of technological devices, including terrestrial and space vehicles, and the enhancement of recreational activities and sports equipment.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to dynamics (e.g., inertial and non-inertial frames of reference);
- analyse and predict, in quantitative terms, and explain the linear motion of objects in horizontal, vertical, and inclined planes;
- analyse and predict, in quantitative terms, and explain the motion of a projectile with respect to the horizontal and vertical components of its motion;
- analyse and predict, in quantitative terms, and explain uniform circular motion in the horizontal and vertical planes with reference to the forces involved;
- distinguish between inertial and accelerating (non-inertial) frames of reference, and predict velocity and acceleration in a variety of situations;
- describe Newton's law of universal gravitation, apply it quantitatively, and use it to explain planetary and satellite motion.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- analyse experimental data, using vectors, graphs, trigonometry, and the resolution of vectors into perpendicular components, to determine the net force acting on an object and its resulting motion;
- carry out experiments or simulations involving objects moving in two dimensions, and analyse and display the data in an appropriate form (e.g., investigate the motion of objects on a horizontal or inclined plane; or the motion of projectiles);
- predict the motion of an object, and then design and conduct an experiment to test the prediction (e.g., verify predictions for such quantities as the time of flight, range, and maximum height of a projectile);
- investigate, through experimentation, the relationships among centripetal acceleration, radius of orbit, and the period and frequency of an object in uniform circular motion; analyse the relationships in quantitative terms; and display the relationships using a graph.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- describe, or construct prototypes of, technologies based on the concepts and principles related to projectile and circular motion (e.g., construct a model of an amusement park ride and explain the scientific principles that underlie its design; explain, using scientific concepts and principles, how a centrifuge separates the components of blood);
- analyse the principles of dynamics and describe, with reference to these principles, how the motion of human beings, objects, and vehicles can be modified (e.g., analyse the physics of throwing a baseball; analyse the frictional forces acting on objects and explain how the control of these forces has been used to modify the design of objects such as skis and car tires).

## Energy and Momentum

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the concepts of work, energy, momentum, and the laws of conservation of energy and of momentum for objects moving in two dimensions, and explain them in qualitative and quantitative terms;
- investigate the laws of conservation of momentum and of energy (including elastic and inelastic collisions) through experiments or simulations, and analyse and solve problems involving these laws with the aid of vectors, graphs, and free-body diagrams;
- analyse and describe the application of the concepts of energy and momentum to the design and development of a wide range of collision and impact-absorbing devices used in everyday life.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to momentum and energy (e.g., momentum, impulse, work-energy theorem, gravitational potential energy, elastic potential energy, thermal energy and its transfer [heat], elastic collision, inelastic collision, open and closed energy systems, simple harmonic motion);
- analyse, with the aid of vector diagrams, the linear momentum of a collection of objects, and apply quantitatively the law of conservation of linear momentum;
- analyse situations involving the concepts of mechanical energy, thermal energy and its transfer (heat), and the laws of conservation of momentum and of energy;
- distinguish between elastic and inelastic collisions;
- analyse and explain common situations involving work and energy, using the work-energy theorem;

- analyse the factors affecting the motion of isolated celestial objects, and calculate the gravitational potential energy for each system, as required;
- analyse isolated planetary and satellite motion and describe it in terms of the forms of energy and energy transformations that occur (e.g., calculate the energy required to propel a spaceship from the Earth's surface out of the Earth's gravitational field, and describe the energy transformations that take place; calculate the kinetic and gravitational potential energy of a satellite that is in a stable circular orbit around a planet);
- state Hooke's law and analyse it in quantitative terms.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- investigate the laws of conservation of momentum and of energy in one and two dimensions by carrying out experiments or simulations and the necessary analytical procedures (e.g., use vector diagrams to determine whether the collisions of pucks on an air table are elastic or inelastic);

- design and conduct an experiment to verify the conservation of energy in a system involving kinetic energy, thermal energy and its transfer (heat), and gravitational and elastic potential energy (e.g., design and conduct an experiment to verify Hooke’s law; develop criteria to specify the design, and analyse the effectiveness, through experimentation, of an “egg-drop” container).
- identify and analyse social issues that relate to the development of vehicles (e.g., analyse, using their own or given criteria, the economic and social costs and benefits of the development of safety devices in automobiles).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- analyse and describe, using the concepts and laws of energy and of momentum, practical applications of energy transformations and momentum conservation (e.g., analyse and describe the operation of a shock absorber, and outline the energy transformations that take place; analyse and explain, using scientific concepts and principles, the design of protective equipment developed for recreational and sports activities; research and explain the workings of a clock);

## Electric, Gravitational, and Magnetic Fields

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the concepts, principles, and laws related to electric, gravitational, and magnetic forces and fields, and explain them in qualitative and quantitative terms;
- conduct investigations and analyse and solve problems related to electric, gravitational, and magnetic fields;
- explain the roles of evidence and theories in the development of scientific knowledge related to electric, gravitational, and magnetic fields, and evaluate and describe the social and economic impact of technological developments related to the concept of fields.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to electric, gravitational, and magnetic fields (e.g., electric and gravitational potential energy, electric field, gravitational field strength, magnetic field, electromagnetic induction);
- state Coulomb's law and Newton's law of universal gravitation, and analyse and compare them in qualitative terms;
- apply Coulomb's law and Newton's law of universal gravitation quantitatively in specific contexts;
- compare the properties of electric, gravitational, and magnetic fields by describing and illustrating the source and direction of the field in each case;
- apply quantitatively the concept of electric potential energy in a variety of contexts, and compare the characteristics of electric potential energy with those of gravitational potential energy;
- analyse in quantitative terms, and illustrate using field and vector diagrams, the electric field and the electric forces produced by a single point charge, two point charges, and

two oppositely charged parallel plates (e.g., analyse, using vector diagrams, the electric force required to balance the gravitational force on an oil drop or on latex spheres between parallel plates);

- describe and explain, in qualitative terms, the electric field that exists inside and on the surface of a charged conductor (e.g., inside and around a coaxial cable);
- predict the forces acting on a moving charge and on a current-carrying conductor in a uniform magnetic field.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- determine the net force on, and resulting motion of, objects and charged particles by collecting, analysing, and interpreting quantitative data from experiments or computer simulations involving electric, gravitational, and magnetic fields (e.g., calculate the charge on an electron, using experimentally collected data; conduct an experiment to verify Coulomb's law and analyse discrepancies between theoretical and empirical values);

- analyse and explain the properties of electric fields and demonstrate how an understanding of these properties can be applied to control or alter the electric field around a conductor (e.g., demonstrate how shielding on electronic equipment or on connecting conductors [coaxial cables] affects electric and magnetic fields).
- describe instances where developments in technology resulted in the advancement or revision of scientific theories, and analyse the principles involved in these discoveries and theories (e.g., analyse the operation of particle accelerators, and describe how data obtained through their use led to enhanced scientific models of elementary particles);

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- explain how the concept of a field developed into a general scientific model, and describe how it affected scientific thinking (e.g., explain how field theory helped scientists understand, on a macro scale, the motion of celestial bodies and, on a micro scale, the motion of particles in electromagnetic fields);
- evaluate, using their own criteria, the social and economic impact of new technologies based on a scientific understanding of electric, gravitational, and magnetic fields.

## The Wave Nature of Light

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the wave model of electromagnetic radiation, and describe how it explains diffraction patterns, interference, and polarization;
- perform experiments relating the wave model of light and technical applications of electromagnetic radiation (e.g., lasers and fibre optics) to the phenomena of refraction, diffraction, interference, and polarization;
- analyse phenomena involving light and colour, explain them in terms of the wave model of light, and explain how this model provides a basis for developing technological devices.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and explain the concepts and units related to the wave nature of light (e.g., diffraction, dispersion, wave interference, polarization, electromagnetic radiation, electromagnetic spectrum);
- describe, citing examples, how electromagnetic radiation, as a form of energy, is produced and transmitted, and how it interacts with matter;
- describe the phenomenon of wave interference as it applies to light in qualitative and quantitative terms, using diagrams and sketches;
- describe and explain the phenomenon of wave diffraction as it applies to light in quantitative terms, using diagrams;
- describe and explain the experimental evidence supporting a wave model of light (e.g., describe the scientific principles related to Young's double-slit experiment and explain how his results led to a general acceptance of the wave model of light).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- identify the theoretical basis of an investigation, and develop a prediction that is consistent with that theoretical basis (e.g., predict diffraction and interference patterns produced in ripple tanks; predict the diffraction pattern produced when a human hair is passed in front of a laser beam; predict effects related to the polarization of light as it passes through two polarizing filters);
- identify the interference pattern produced by the diffraction of light through narrow slits (single and double slits) and diffraction gratings, and analyse it in qualitative and quantitative terms;
- collect and interpret experimental data in support of a scientific theory (e.g., conduct an experiment to observe the interference pattern produced by a light source shining through a double slit and explain how the data supports the wave theory of light);
- analyse and interpret experimental evidence indicating that light has some characteristics and properties that are similar to those of mechanical waves and sound.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe instances where the development of new technologies resulted in the advancement or revision of scientific theories (e.g., outline the scientific understandings that were made possible through the use of such devices as the electron microscope and interferometers);
- describe and explain the design and operation of technologies related to electromagnetic radiation (e.g., describe the scientific principles that underlie Polaroid filters for enhancing photographic images; describe how information is stored and retrieved using compact discs and laser beams);
- analyse, using the concepts of refraction, diffraction, and wave interference, the separation of light into colours in various phenomena (e.g., the colours produced by thin films), which forms the basis for the design of technological devices (e.g., the grating spectroscope).

## Matter-Energy Interface

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the basic concepts of Einstein's special theory of relativity and of the development of models of matter, based on classical and early quantum mechanics, that involve an interface between matter and energy;
- interpret data to support scientific models of matter, and conduct thought experiments as a way of exploring abstract scientific ideas;
- describe how the introduction of new conceptual models and theories can influence and change scientific thought and lead to the development of new technologies.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to the present-day understanding of the nature of the atom and elementary particles (e.g., radioactivity, quantum theory, photoelectric effect, matter waves, mass-energy equivalence);
- describe the principal forms of nuclear decay and compare the properties of alpha particles, beta particles, and gamma rays in terms of mass, charge, speed, penetrating power, and ionizing ability;
- describe the photoelectric effect in terms of the quantum energy concept, and outline the experimental evidence that supports a particle model of light;
- describe and explain in qualitative terms the Bohr model of the (hydrogen) atom as a synthesis of classical and early quantum mechanics;
- state Einstein's two postulates for the special theory of relativity and describe related thought experiments (e.g., describe Einstein's thought experiments relating to the constancy of the speed of light in all inertial frames of reference, time dilation, and length contraction);

- apply quantitatively the laws of conservation of mass and energy, using Einstein's mass-energy equivalence;
- describe the Standard Model of elementary particles in terms of the characteristic properties of quarks, leptons, and bosons, and identify the quarks that form familiar particles such as the proton and neutron.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- collect and interpret experimental data in support of a scientific theory (e.g., conduct an experiment, or view prepared slides, to analyse how the emission spectrum of hydrogen supports Bohr's predicted transition states in his model of the atom);
- conduct thought experiments as a way of developing an abstract understanding of the physical world (e.g., outline the sequence of thoughts used to predict effects arising from time dilation, length contraction, and increase of mass when an object travels at several different velocities, including those that approach the speed of light);
- analyse images of the trajectories of elementary particles to determine the mass-versus-charge ratio;

- compile, organize, and display data related to the nature of the atom and elementary particles, using appropriate formats and treatments (e.g., using experimental data or simulations, determine and display the half-lives for radioactive decay of isotopes used in carbon dating or in medical treatments).
- describe how the development of the quantum theory has led to scientific and technological advances that have benefited society (e.g., describe the scientific principles related to, and the function of, lasers, the electron microscope, or solid state electronic components);

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- outline the historical development of scientific views and models of matter and energy, from Bohr's model of the hydrogen atom to present-day theories of atomic structure (e.g., construct a concept map of scientific ideas that have been developed since Bohr's model, and outline how these ideas are synthesized in the Standard Model);
- describe examples of Canadian contributions to modern physics (e.g., contributions to science and society made by Bert Brockhouse, Werner Israel, Ian Keith Affleck, Harriet Brooks, Richard Taylor, or William George Unruh).

## Physics, Grade 12, College Preparation

(SPH4C)

This course develops students' understanding of the basic concepts of physics. Students will explore these concepts as they relate to mechanical, electrical, fluid (hydraulic and pneumatic), and communications systems, as well as to the operation of commonly used tools and equipment. They will develop scientific-inquiry skills as they verify accepted laws of physics and solve both assigned problems and those emerging from their investigations. Students will also consider the impact of technological applications of physics on society and the environment.

**Prerequisite:** Science, Grade 10, Academic or Applied

***Throughout this course, students will:***

- demonstrate an understanding of appropriate safety practices by selecting, operating, and storing electrical equipment, components, and materials in accordance with the Ontario Electrical Code, and by acting in accordance with Workplace Hazardous Materials Information System (WHMIS) legislation in selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., wear appropriate protective goggles and clothing when soldering electrical connections or carrying out experiments involving fluids under pressure);
- select appropriate instruments and testing equipment and use them effectively and accurately in collecting observations and data (e.g., troubleshoot electrical circuits using electrical tools and such measuring instruments as ammeters, voltmeters, and oscilloscopes);
- demonstrate the skills required to design and carry out experiments related to the topics under study, controlling major variables and adapting or extending procedures where required (e.g., design and carry out an experiment to determine the relationships among force, area, pressure, volume, and time in a hydraulic system);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., explain the reflection and refraction of light in various situations, using ray diagrams);
- use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena;
- analyse and synthesize information for the purpose of identifying problems for inquiry, and solve the problems using a variety of problem-solving skills;
- select and use appropriate SI units, and apply unit analysis techniques when solving problems;

- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation (e.g., algebraic equations, vector diagrams, free-body diagrams, ray diagrams, graphs, graphing programs, spreadsheets) to communicate scientific ideas, plans, and experimental results;
- communicate the procedures and results of investigations and research for specific purposes using data tables, laboratory reports, and research papers, and account for discrepancies between theoretical and experimental values (e.g., compile a table listing the efficiencies of the energy transformations that occur in the operation of some transducers used in communications systems);
- express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- identify and describe science- and technology-based careers related to the subject area under study (e.g., filmmaker, kinesiologist, navigator, tool-and-die maker, machinist, fluid power technologist, communications technician).

## Mechanical Systems

### Overall Expectations

By the end of this course, students will:

- describe and apply concepts related to forces, Newton's laws of motion, static and kinetic friction, simple machines, torques, and mechanical advantage;
- design and carry out experiments to investigate forces, coefficients of friction, and the operation of simple machines;
- identify and analyse applications of applied forces, friction, and simple machines in real-world machines and in the human body.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to force, coefficients of friction, torque, mechanical advantage, and work;
- state Newton's laws of motion, and apply them to mechanical systems (e.g., identify and explain the conditions associated with the movement of objects at constant velocity);
- analyse, in qualitative and quantitative terms, the forces (e.g., gravitational forces, applied forces, friction forces) acting on an object in a variety of situations, and describe the resulting motion of the object;
- identify, describe, and illustrate applications of types of simple machines, that is, the inclined plane and the lever, and modifications of these (the wedge, the screw, the pulley, and the wheel and axle);
- apply quantitatively the relationships among torque, force, and displacement in simple machines;
- state the law of the lever, and apply it quantitatively in a variety of situations for all three classes of levers;
- explain the operation and mechanical advantage of simple machines;
- determine the mechanical advantage of a variety of compound machines and bio-mechanical systems.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- verify Newton's second law of motion through experimentation;
- determine, through experimentation, the factors affecting static and dynamic friction and the corresponding coefficients of friction;
- select appropriate instruments and use them effectively and accurately in investigating the relationships among force, displacement, and torque for the load arm and effort arm of levers;
- analyse, in quantitative terms, a mechanical system with respect to its component simple machines, input and output forces, and mechanical advantage (e.g., determine the mechanical advantage of the simple machines in a bicycle);
- construct a simple or compound machine to solve a practical problem, and determine its mechanical advantage (e.g., design and construct a prototype of a machine for lifting a patient from a hospital bed, calculate the mechanical advantage of each of the simple machines used in the device, and explain the operation of each simple machine).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe advantages and disadvantages of friction in real-world situations, as well as methods used to increase or reduce friction in these situations (e.g., advantages of, and methods for increasing, friction on the surface of car tires and the soles of mountain-climbing boots; disadvantages of, and methods for reducing, friction between moving parts on industrial machines, and on wheels spinning on axles);
- describe the role of machines in everyday domestic life and in industry (e.g., identify simple machines that are part of a device used in the home, and explain the function of each machine; explain the function of the simple machines used in one of the following: robotics equipment, pulley systems, lever systems on backhoes, bulldozers, winches, the “Canadarm”);
- analyse natural and technological systems that employ the principles of simple machines, and explain their function and structure (e.g., analyse the operation of the human arm in terms of the operation of a lever).

## Electricity and Electronics

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of common applications of electrical and electronic circuits, and the function and configuration of the components used;
- construct, analyse, and troubleshoot simple electrical circuits by using schematic diagrams and appropriate electrical tools and measuring equipment, and by examining familiar electrical devices;
- investigate the development and application of electrical technologies and their impact on local and global economies and the environment.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to electrical and electronic systems (e.g., direct current, alternating current, electric potential, resistance, power, energy);
- compare direct current and alternating current in qualitative terms, and describe situations in which each is used;
- describe the function of basic circuit components (e.g., power supplies, resistors, diodes, fuses, circuit breakers, light-emitting diodes [LEDs], capacitors, and switching devices);
- analyse and describe the operation of electrical and electronic devices that control other systems (e.g., programmable thermostats, control switches for fans or pumps, logic circuits, security systems, smoke detectors);
- analyse, in quantitative terms, circuit problems involving potential difference, current, and resistance;
- distinguish between, and explain the functions of, analog and digital circuits (e.g., identify one device that requires an analog circuit to function – audio amplifier, audio-tape recorder – and another that

requires a digital circuit – computer data storage device, alarm circuit, compact disc [CD] recording, digital video disc [DVD] – and explain why each kind of circuit is used);

- describe examples of electrical sub-circuits that are micro-miniaturized and used as “black boxes” that serve a particular purpose in electronic equipment (e.g., identify and describe the function of a computer central processing unit [CPU] and a “smart” telephone card).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use appropriate meters (analog or digital), computer probes, and oscilloscopes to measure electric potential difference, current, and resistance in electrical circuits;
- construct simple electrical circuits using common tools appropriately and safely (e.g., soldering irons, wire strippers, crimping tools, screwdrivers, common connectors);
- draw, by hand or using a computer, schematic diagrams to represent real circuits;
- analyse, in quantitative terms, real or computer-simulated circuits, using Ohm’s law and Kirchhoff’s rules;

- design and construct an electrical circuit to perform a simple function (e.g., perimeter security system, water-level detector), and evaluate it on the basis of specified criteria;
- analyse real or simulated circuits to identify faults and suggest corrective changes (e.g., analyse the operation of a small home appliance and identify the problem in one that is broken or defective).
- investigate the use and historical development of an electrical or electronic appliance or device (e.g., dry-cell, rechargeable battery, toaster, refrigerator, computer), and describe its performance since its development with respect to safety, cost, availability, and environmental impact;
- identify and describe proper safety procedures to be used when working with electrical circuits, and identify electrical hazards that may occur in the science classroom or at home.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe common applications of simple circuits, and identify the energy transformations that occur (e.g., energy transformations in one of the following appliances or devices: refrigerator, kettle, food mixer, amplifier, television set, light bulb, oscillator, electromagnet, electric motor, garage door opener);

## Hydraulic and Pneumatic Systems

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the scientific principles related to fluid statics and dynamics, and to hydraulic and pneumatic systems;
- design and carry out investigations of fluid statics and dynamics, and of simple hydraulic and pneumatic systems;
- analyse and describe the social and economic consequences of the development of technological applications related to the motion and control of fluids.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to fluids and to hydraulic and pneumatic systems (e.g., density, atmospheric pressure, absolute pressure, laminar and turbulent flow, static pressure head, pressure, volume, flow rate);
- identify factors affecting laminar flow, and describe examples of laminar flow (e.g., identify the factors affecting the streamlining of cars, boats, planes, turbine blades, propellers, golf balls, or shark skin, and describe how each of these factors has been considered in the design of at least one of these applications);
- state Bernoulli's principle and explain some of its applications in the fields of technology and health (e.g., explain spray atomizers, propellers, spoilers on racing cars, turbine blades in jet engines);
- identify factors affecting static pressure head, analyse static pressure head in quantitative terms, and explain its effects in liquids and gases (e.g., identify factors affecting static pressure head in the Earth's atmosphere and calculate the absolute pressure at 5000 m);
- state Pascal's principle and explain its applications in the transmission of forces in fluid systems;
- describe common components used in hydraulic and pneumatic systems (e.g., cylinders, valves, motors, fluids, hoses, connectors, pumps, reservoirs);
- apply quantitatively the relationships among force, area, pressure, volume, and time in hydraulic and pneumatic systems (e.g., calculate the force exerted by the hydraulically operated brake pad on the wheel of a motorcycle or car; calculate the time required for a robotic system to complete one cycle of operation);
- analyse, in quantitative terms, the relationships among work, power, and time in hydraulic and pneumatic circuits.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- demonstrate Bernoulli's principle through experiments (e.g., experiments involving wind tunnel demonstrations, suspension of table tennis balls, blowing between pieces of paper, or use of a Venturi tube);
- identify factors that affect the static pressure head in fluids by carrying out procedures, compare theoretical and empirical values, and account for discrepancies;
- verify Pascal's principle through experimentation;

- draw simple hydraulic or pneumatic circuits, using correct circuit symbols;
- determine, through experimentation, the relationships among force, area, pressure, volume, and time in a hydraulic or pneumatic system (e.g., build a two-cylinder circuit using small plastic cylinders filled with air or water, and measure and quantitatively analyse the extension of the cylinders and the forces exerted by them);
- design, construct, and evaluate a hydraulic or pneumatic system (e.g., the braking system on a car; a clamping device; a model of a crane) and solve problems as they arise.
- identify and analyse some of the social and economic consequences of the use of robotic systems for many different kinds of operations (e.g., identify examples of the use of robotic systems in the computer-manufacturing industry, for lifting and manoeuvring heavy objects on assembly lines in factories, for handling hazardous materials, and for activities under water and in space, and explain how the use of robotics has affected the training required of people employed in these industries);
- identify various applications of hydraulic and pneumatic systems in everyday life, and evaluate the impact of the use of these systems on the quality of life.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe the historical development of fluid systems, analyse their design, and determine why these technologies were developed and improved (e.g., identify examples of the use of hydraulic systems in aircraft and other transportation vehicles, in heavy equipment, and in precision machining, and explain why they have become the preferred system for each of the identified uses);

## Communications Technology

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the scientific principles and technological applications involved in the design, development, and operation of communications systems;
- design and carry out experiments to investigate and illustrate the fundamental operating principles and basic components of communications systems;
- identify and describe Canadian contributions to communications technology, and demonstrate awareness of the wide-ranging and ever-growing influence of communications technology on the global community.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and explain the concepts and units related to communications technology (e.g., frequency, period, cycle, wavelength, amplitude, longitudinal and transverse waves, electromagnetic waves, reflection, refraction, total internal reflection, interference, transmission, absorption);
- describe the periodic motion of a vibrating object in qualitative terms, and analyse it in quantitative terms (e.g., the motion of a pendulum, a vibrating spring, a tuning fork);
- describe the characteristics of waves, and analyse, in quantitative terms, the relationships among velocity, frequency, and wavelength to explain the behaviour of waves in different media;
- explain and illustrate the principle of superposition of waves (e.g., explain the sound produced by a musical instrument in terms of its fundamental frequency and the associated overtones, and draw diagrams to show the relationships between them);
- describe how the interference of waves is used in communications technology;
- explain, in qualitative terms, and illustrate how the reflection of waves is used in communications technology (e.g., in loudspeaker enclosures, police radar, communications satellites, parabolic reflectors);
- explain and predict, in quantitative terms and with the use of Snell's law, the refraction of electromagnetic waves;
- describe and illustrate total internal reflection, and explain its significance in communications systems;
- analyse and describe the sequences of energy transformations and transmissions that occur in commonly used communications systems (e.g., analyse and describe the function of each of the energy transformations that occur in a sound system, a video camera, a video cassette recorder [VCR], and a television set).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- determine, through experimentation, the properties of and the relationships among the major variables for a vibrating object (e.g., conduct an experiment to determine the factors that affect the frequency of a pendulum);

- investigate, through experimentation or the use of computer simulations, the characteristics of transverse and longitudinal mechanical waves (e.g., conduct experiments, using slinkies, springs, wave machines, ripple tanks);
- demonstrate and explain the principle of superposition (e.g., explain the production of standing waves, overtones in musical instruments, beats in sound waves, amplitude and frequency modulation in radio waves);
- verify Snell's law through experimentation, and identify the conditions required for total internal reflection;
- investigate the reflection and refraction of light through experimentation, and interpret results using algebraic and geometric models (e.g., investigate reflection of light from differently shaped surfaces, refraction of light in different media, and total internal reflection);
- analyse, in qualitative terms, the operation of simple transducers used in communications systems or in information-processing equipment (e.g., in microphones, loudspeakers, tape recorder heads, remote controllers, product code readers), and describe the energy transformations that occur;
- design and construct a simple communications system, and demonstrate the operation of each of the major components in the system (e.g., design and construct a simple house intercom system).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- evaluate, using their own criteria, available models of a particular communications system or device (e.g., cell phone, computer system, satellite data transmission system, home entertainment system), and determine which model is the best on the basis of their evaluation;
- describe and evaluate Canadian contributions to communications science and technology (e.g., evaluate the contributions of Alexander Graham Bell, Reginald A. Fessenden, the Canadian communications industry, or the Canadian satellite and space exploration industry);
- assess, using their own criteria, the risks and benefits to society and the environment of introducing a particular technology from the communications industry (e.g., consider such factors as effects on personal privacy, control of the mass media, criminal activities, health concerns related to electric and magnetic fields, and the transfer of information).

## Energy Transformations

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of forms of energy, energy sources, energy transformations, energy losses, and efficiency, and the operation of common energy-transforming devices;
- construct or investigate devices that involve energy sources, energy transformations, and energy losses, and assess their efficiency;
- analyse and describe the operation of various technologies based on energy transfers and transformations, and evaluate the potential of energy-transformation technologies that use sources of renewable energy.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and describe the concepts and units related to energy transformations (e.g., energy, forms of energy, power, efficiency);
- describe and compare various energy transformations (e.g., describe energy transformations among mechanical, sound, thermal, electromagnetic, gravitational, and nuclear forms of energy);
- describe, with the aid of diagrams, the operation of energy-transforming devices (e.g., electric motors and generators, heat engines, photoelectric cells, electrochemical cells);
- analyse and describe, using energy flow diagrams, the relationships among and efficiencies of various energy sources (e.g., the sun, natural gas, oil, coal, moving water), transformations (e.g., between thermal energy and its transfer [heat] and electrical energy), transmissions (e.g., of electrical energy), and energy losses (e.g., of electrical energy as a result of resistance);
- determine, in quantitative terms, the power and efficiency of energy transformations in some common devices (e.g., electric motor, internal combustion engine, incandescent light bulb, fluorescent light bulb).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- determine, through experimentation, the efficiency of a simple process of energy transformation (e.g., a rubber band stretched to propel a cart through photo-gates; an electric motor used to lift a mass);
- collaboratively design and build a device that uses at least four functional energy transformations to complete a task (e.g., an alarm system for a house), and explain its operation.

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- analyse and describe examples of technologies based on various combinations of energy transfer and transformation (e.g., a shock absorber, a vehicular airbag, a Mars landing system);
- evaluate the benefits and drawbacks, with respect to such factors as economic viability, use of energy resources, efficiency, safety, and general utility, of energy-transforming devices based on sources of renewable energy (e.g., photoelectric cells, solar cookers, hydrogen fuel cells, wind-up radios, Archimedes' pumps).

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# Science

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## Science, Grade 11, University/College Preparation

(SNC3M)

This course enables students, including those who do not intend to pursue science-related programs at the postsecondary level, to increase their understanding of science and its technological applications. Students will explore a range of topics, including the safe use of everyday chemicals; the science of nutrition and body function; waste management; the application of scientific principles in space; and technologies in everyday life. Emphasis will be placed on the role of science and technology in daily life and in relation to social and environmental issues.

**Prerequisite:** Science, Grade 10, Academic or Applied

***Throughout this course, students will:***

- demonstrate an understanding of safety practices consistent with Workplace Hazardous Materials Information System (WHMIS) legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., safely handle acids, bases, and other aqueous solutions);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., laboratory glassware, balances, pH meters, data loggers);
- demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., investigate the acid-base reactions of some household cleaners);
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., data tables illustrating the caloric content of various diets; concept maps);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites (e.g., compile a cost-benefit analysis of the environmental impact of a technology);
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams;
- communicate the procedures and results of laboratory investigations and research for specific purposes, using data tables and laboratory reports (e.g., present the findings of an investigation of the physical and chemical properties of everyday chemicals or of the effects of modern technologies on food preservation);
- research and evaluate specialized knowledge, and apply it to the world outside the school (e.g., evaluate the costs and benefits of an everyday technology to an individual and to society; explain the development of advanced composite materials as a result of research in space);
- select and use appropriate SI units (units of measurement of the *Système international d'unités*, or International System of Units);
- identify and collect information on careers related to the subject area under study (e.g., information on the educational background, aptitudes, required skills, typical tasks, and salary range for a career in the manufacturing of chemical products).

## Everyday Chemicals and Safe Practice

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the properties, benefits, and hazards of everyday chemicals, and of the safe use of these products in the home, the workplace, and industry;
- investigate, through laboratory experiments and computer simulations, the chemical and physical properties of representative types of everyday chemicals, using appropriate equipment safely and accurately;
- evaluate the advantages and disadvantages of the use of common types of chemicals in everyday life, and analyse the environmental/economic impact of their use.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define and give examples of such chemical terms as *corrosive product*, *acid*, *base*, *organic solvent*, *fuel*;
- explain how chemical and physical characteristics of everyday substances are the result of differences in the bonding of their constituent parts (e.g., covalent, polar covalent, ionic bonds, metallic bonding);
- give evidence for, and classify the types of, reactions involving everyday chemicals (e.g., combustion, displacement, acid-base reactions);
- explain the properties and current uses of everyday chemicals (e.g., corrosive products, solvents, fuels, household products);
- describe the effects of everyday chemicals (e.g., acid emissions, carbon emissions, CFCs, PCBs) on the well-being of organisms, including humans;
- explain the hazards and safe handling of everyday chemicals as outlined on material safety data (MSD) sheets (e.g., safe practices in the mixing, storage, and transportation of chemicals in an experimental investigation).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- use laboratory equipment and handle everyday chemicals (e.g., mix, store, transport them) in accordance with accepted safety practices (e.g., practices in WHMIS legislation, the Fire Code, the Occupational Health and Safety Act);
- design and conduct experiments to illustrate the chemical and physical properties of representative types of everyday chemicals (e.g., household products such as vinegar and baking soda);
- identify, using data collected through experimentation or computer simulation, the types of chemical reactions displayed by everyday chemical products (e.g., precipitation, neutralization);
- represent, using simple models of certain compounds, the relationship between structure and physical/chemical properties (e.g., in acids, bases, gasoline);
- predict the benefits and dangers associated with the everyday use of chemicals (e.g., the use of vinegar to clean glass), drawing on information from a variety of sources, including experimental findings and information printed on container labels.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- explain the different chemical waste management strategies used in urban, rural, and industrial situations (e.g., strategies for managing septic tanks, grey water, sewer systems);
- analyse the costs and benefits to society of selected chemical products (e.g., corrosive products such as acids and bases), and assess the impact of their use in the community;
- assess the environmental impact of the increased use of chemicals in the manufacturing of new products used in the home, workplace, and industry.

## Body Input and Body Function

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of food components and their effects on body functions;
- make inferences regarding the impact of eating patterns on body function, based on an analysis of data gathered through laboratory investigations and from print and electronic sources;
- explain how personal and societal factors affect eating behaviours, and evaluate the social and economic impact of the use of non-nutrient food additives.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define such terms as the following, and give examples of each: *lipid* (e.g., saturated fatty acid), *carbohydrate* (e.g., monosaccharide, polysaccharide), *protein* (e.g., the amino acid building blocks, essential amino acid), *vitamin* (e.g., fat-soluble vitamin), *mineral*;
- identify the sources, basic chemical structure, and function in the body of the principal food nutrients (e.g., carbohydrates, lipids, proteins, vitamins, minerals);
- explain the role and importance of fibre in the diet (e.g., fruit fibre, bran);
- identify the factors that contribute to energy use in the body (e.g., exercise, diet, drug use/abuse);
- describe the role of non-nutrient food additives (e.g., lecithin, monosodium glutamate [MSG], food colouring), and explain their impact on body function;
- explain how diets that include excessive amounts of certain foods may influence the balance of body functions (e.g., examine diets high in cholesterol and salt, and explain their relationship to blood pressure and heart function);
- describe the causes and symptoms of a number of eating disorders (e.g., anorexia, bulimia).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- determine, through investigations, the nutrient or energy content in selected food samples (e.g., hamburger, bread);
- determine, through investigations, how certain factors affect body function (e.g., the impact of exercise and tobacco on cardiovascular function);
- determine the effect of non-nutrient food additives (e.g., caffeine) on the body through analysis of data collected with a variety of information-gathering devices (e.g., a sphygmomanometer, stethoscope, respirometer);
- assess a variety of popular diets with respect to their inclusion of the main nutrient groups in appropriate amounts (e.g., gather and integrate information on calories and nutrients in representative diets in relation to Canada's Food Rules, and assess their adequacy);
- assess strategies for monitoring and maintaining personal health (e.g., analyse data from a case study on symptoms of fatigue, high blood pressure, and chest pain, and explain how the data may be used to help maintain personal health).

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- analyse the social and economic costs and benefits of the use of non-nutrient food additives in food preservation and food enhancement techniques (e.g., the use of non-nutrient food additives to preserve food/fruit freshness; additives for flavour/colour enhancement);
- evaluate the impact of some personal and societal factors (e.g., allergies, disease, body image) on eating behaviours (e.g., assess the relationship between ideas of beauty and students' interest in “fad” diets), and describe some of the benefits of a nutritious diet for personal health and lifestyle;
- assess the costs and benefits to society of certain eating behaviours (e.g., eating of highly processed foods, natural foods; adoption of a vegetarian diet).

# Waste Management

## Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the nature and types of waste and of their management in industry and the community;
- conduct investigations/research and make inferences regarding the effectiveness of various waste management practices;
- describe and analyse the interaction of science, society, and government in the development of various waste management strategies, and assess the impact of various wastes on the environment.

## Specific Expectations

### *Understanding Basic Concepts*

By the end of this course, students will:

- define, and when appropriate give examples of, such terms as the following: *solid/liquid/gaseous waste, toxic waste, heavy metals, chlorinated hydrocarbons, acid rain, ozone, greenhouse effect*;
- explain the principles related to the management of solid waste (e.g., industrial, toxic, medical, nuclear solid waste);
- explain the principles related to the management of liquid waste (e.g., gather data on a field trip to a sewage treatment facility and explain the scientific basis of the procedures involved in the management of human waste);
- explain the principles related to the management of gaseous waste (e.g., principles underlying management strategies aimed at minimizing global ozone depletion);
- explain how science and technology are used in the development of new waste management strategies (e.g., explain the scientific and technological principles related to biological filters, catalytic converters, lead-free gasolines, and industrial scrubbers).

### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- investigate, through experimentation, the relationship between a type of waste produced (e.g., solid, liquid, gas) and waste management strategies (e.g., conduct an experiment to maximize nutrient levels in a closed composting system; minimize acidity in a closed bog system in an aquarium; or regulate methane gas levels in a closed system of decomposing grass in a bottle);
- communicate effectively the results of research on the use and management of a resource and the resulting waste that is generated (e.g., select and integrate information on the disposal of waste in mining or forestry);
- describe and explain, through research and reporting, the use of bacteria as waste decomposers (e.g., write an essay on the use of bacteria in sewage treatment plants, septic-tank systems, and the clean-up of oil spills);
- evaluate the advantages and disadvantages of alternative waste management systems (e.g., assess the evidence for the assumed benefits of reclaiming sulphur from exhaust gases for selected industries).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- illustrate, through research into a category of household waste, the effects of waste on the environment (e.g., the effects of solids, liquids, and gases resulting from the use of cleaning agents or paint strippers);
- analyse the impact of economic and political considerations on the choice of waste management strategies and ultimately on the environment (e.g., analyse and assess the policies of a local sewage treatment plant);
- evaluate the short- and long-term impact of a specific waste on the environment, and make recommendations for change (e.g., assess the possible effects of nuclear waste and its disposal, and suggest alternatives to nuclear energy);
- advocate for an improved waste management system at the local, regional, or national level of government (e.g., create a local action plan outlining suggested changes).

## Science and Space

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the space environment and the effects of microgravity (or of the elimination of gravity-driven phenomena) on space exploration;
- demonstrate safe use of scientific equipment to explore qualitatively the differences in space of various processes and of the behaviour of various materials;
- explore the human and technological benefits, and the limitations, of developing technologies for use in space, or of using existing technologies in space.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define, and when appropriate give examples of, such concepts as the following: gravity, microgravity, Newton’s law of universal gravitation, crystallization, surface tension;
- describe how Newton’s laws of motion and his law of universal gravitation explain the phenomenon of gravity and the necessary conditions of microgravity and “weightlessness”;
- compare, by conducting research, the various ways of simulating a microgravity environment (e.g., through the use of aircraft, rockets, drop towers, and orbiting spacecraft);
- describe the medical effects of space flight on the human body (e.g., produce a chart to show the cause-and-effect relationships between prolonged exposure to the space environment and bone demineralization, muscle degradation, and motion sickness);
- explain the scientific principles involved in the crystallization of certain materials (e.g., alum, d-mannitol, phenyl salicylate, triglycine sulphate) on the Earth’s surface;

- identify the scientific principles involved in the behaviour of fluids on the Earth’s surface, and describe how that behaviour would change in an orbiting spacecraft (e.g., describe the effects of changes in temperature on the surface tension of cooking oil).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- simulate the effects of space flight on the human body (e.g., simulate the effect of space on fluid shift, or “puffy-head, bird’s-legs” syndrome, by elevating the feet, while prone, for fifteen minutes);
- illustrate, through laboratory investigation, the characteristics of crystal growth on Earth and compare results, where possible, to those achieved in space (e.g., collect and record data on the growth of alum, and hypothesize how the data would be similar or different if the process were repeated in a microgravity environment);
- illustrate, through laboratory investigation, the effects of Earth’s gravity on the behaviour of fluids (e.g., conduct an experiment on the effects of gravity on surface tension and the effects of differences in surface tension on fluid flows);

- investigate, through experimentation, the nature of materials incorporated in the design of instruments and tools used in space (e.g., design and build a robot arm and describe tests to evaluate its performance in a space environment versus a one-g environment, or on Earth).
- investigate challenges related to survival of humans in space (e.g., the impact of radiation, lower gravity, and atmospheric conditions on the human body in space);
- propose, on the basis of research and group discussion, various solutions to one or more survival challenges to humans in space (e.g., explain how regular exercise can minimize muscle degradation in humans during extended stays in space).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe how research into the behaviour of solids or liquids in space has benefited society (e.g., research on calcium and bone loss with extended time in space has implications for the treatment of osteoporosis);
- explain the benefits to society of a recent example of space technology developed by Canada or by another country (e.g., the societal benefits of a space technology such as Radarsat);

## Technologies in Everyday Life

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the principles of science underlying applications of technology in everyday life;
- analyse, organize, and present information on everyday technologies, using the appropriate laboratory, research, and reporting skills;
- identify and analyse issues involving societal impact and change related to modern everyday technologies.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- formulate definitions of such terms as the following: *science, technology, information technology, reverse engineering, system, testing, feedback, control, human interface, cost-benefit-risk analysis*;
- describe the historical development of specific examples of everyday technology (e.g., information technology, biotechnology);
- explain fundamental scientific principles (e.g., electrical resistance, gene mutation) related to an example of an everyday technology (e.g., the microprocessor, *in vitro* fertilization);
- demonstrate an understanding of the historical relationship between science and technology by tracing the evolution of a common technology over time in relation to developments in science (e.g., pumps to take water from mines; vacuum tubes; cathode ray tube [CRT] displays; transistors and integrated circuits).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- demonstrate, through their own research and its presentation, an understanding of ethical, environmental, and economic issues that involve various viewpoints on the use of technologies in everyday life (e.g., issues in forestry, agriculture, manufacturing, medicine, transportation);
- evaluate the design and function of an everyday technology using identified criteria (e.g., safety, cost, environmental impact, appearance);
- analyse a principle of physics (e.g., capillary action, heat expansion of metal) through laboratory investigation, and explain how it can be applied to an everyday technology (e.g., a motion detector, a thermostat);
- analyse a biological process through laboratory investigation, and explain how it can be applied to an everyday technology (e.g., ask a testable question, propose a hypothesis, and conduct an experiment related to the control of bacterial growth and food preservation);

- analyse a chemical phenomenon (e.g., oxidation/reduction reactions) through laboratory investigation, and explain how it can be applied to an everyday technology (e.g., investigate the components of a simple galvanic cell).
- describe the importance of contributions of Canadian scientists (e.g., W. Penfield, Michael Smith) to the development of modern everyday technologies;
- assess the costs and benefits to society of recent technologies (e.g., the impact of new technologies on human mortality, longevity, health care).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe the changes in lifestyle created by assumed labour-saving technologies in the home (e.g., online banking, in-home Internet shopping);
- identify and describe the effect of technologies on the development of specific recreational or cultural activities (e.g., computerization in the music industry, new materials used in ski equipment or clothing);

## Science, Grade 11, Workplace Preparation

(SNC3E)

This course provides students with the science-related knowledge and skills they need to help them make informed decisions in the workplace and in their personal lives. Students will explore a range of topics, including materials and safety; electrical circuits; micro-organisms; the human immune system and defences against disease; and the impact of humans on the environment. Emphasis is placed on relating these topics directly to students' experiences both in the world of work and in daily life.

**Prerequisite:** Science, Grade 9, Academic or Applied

***Throughout this course, students will:***

- demonstrate an understanding of safe laboratory practices by wearing appropriate protective equipment when working in the laboratory, and by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., handle acids, bases, and other aqueous solutions safely);
- select appropriate apparatus and instruments and use them effectively and accurately in collecting observations and data (e.g., balances, microscopes, multimeters, data loggers);
- demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., investigate the effects of pollutants on a local ecosystem);
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., write chemical formulae for some chemical substances);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., in a table, present data on the beneficial effects of algae ponds, or of consumer reports on appliances);
- communicate the procedures and results of laboratory investigations and research for specific purposes, using data tables and laboratory reports (e.g., describe in a laboratory report the procedures used to investigate the behaviour of bacteria);
- select and use appropriate SI units;
- identify and collect information on science- and technology-based careers related to the subject area under study (e.g., information, including the educational requirements, on a career as a firefighter or electronic service technician).

## Materials and Safety

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of WHMIS legislation and general safety procedures as they apply to materials in the workplace and the home;
- demonstrate safe handling, storage, and disposal procedures for a variety of materials, including some hazardous materials, in the school laboratory (e.g., safely handle solvents, oxidizing agents, acids, bases);
- describe practices that promote fire safety, as well as safety in the handling and disposal of materials, in everyday living in the home and workplace.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- categorize hazardous chemicals as flammable, as reactive, or as harmful to health;
- demonstrate an understanding of important safety legislation (e.g., WHMIS legislation, the Fire Code, the Building Code, the Occupational Health and Safety Act);
- describe factors that affect the rate of chemical reaction, paying special attention to what makes reactions dangerous (e.g., increasing the temperature at which a reaction takes place can cause an explosion; volatile liquids and dispersed powders have a greater rate of reaction);
- identify some oxidizing agents by name and/or chemical formula, and describe their chemical reactivity with fuels and other oxidizable substances (e.g., write the chemical formula for oxygen gas and explain the reaction of oxygen gas with a fuel in terms of the products formed);
- predict the reactivity of metal elements with other chemical substances, using the activity series of metals (e.g., predict the reactivity of metals with acids and oxygen);
- describe the factors that increase the danger of flammable substances (e.g., flash point, auto-ignition);
- identify and explain common types of incompatibility between classes of chemicals (e.g., acids must not be stored on the same shelf as bases);
- demonstrate an understanding of the toxicity and hazards of some chemical substances (e.g., mercury);
- describe routes of entry of hazardous materials into the body (e.g., ingestion, inhalation, absorption through the skin);
- explain the meaning of the terms *acute* and *chronic* as they apply to the effect of hazardous materials on the body.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- formulate scientific questions, in qualitative terms, about rates of chemical reaction (e.g., How do the rates of combustion of some fuels in air differ? What happens to the rates of combustion of fuels in pure oxygen or when mixed with a solid oxidant?);

- demonstrate an understanding of WHMIS legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., use appropriate personal protection, and demonstrate proper housekeeping and knowledge of emergency procedures, when handling chemicals in the laboratory);
- plan and carry out investigations using laboratory equipment effectively, safely, and accurately (e.g., compare the corrosive action of acids on various metals, and collect and test the hydrogen produced by this action; prepare and use a foam fire extinguisher);
- determine, through experimentation, the ease of combustion of various flammable liquids (e.g., compare the ease of combustion of small quantities of alcohol, varsol, mineral oil, or vegetable oil);
- demonstrate, in oral and in written reports, a thorough knowledge of the terminology and symbols used in WHMIS (e.g., correctly interpret material safety data [MSD] sheets, labelling symbols, and acronyms such as LD<sub>50</sub>, LC<sub>50</sub>, TWAEV, STEV, CEV).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- identify and analyse the different aspects of fire safety, including fire prevention and inspection in the home, school, and workplace (e.g., the use of appropriate sources of heat in the kitchen or laboratory; the appropriate use of various types of fire extinguishers and other methods for extinguishing fires; the need for a planned evacuation route at home and at school);
- investigate and report on a topic related to the safe handling, storage, and disposal of hazardous materials, focusing on some specific examples (e.g., the hazards of disposing of chemicals and drugs in rural and urban water systems; local means of disposing of hazardous materials; hazardous materials in the home; application of WHMIS in the use of materials in a local workplace).

## Electrical Circuits

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the components and functions of electrical circuits that are commonly found at home and in the workplace;
- construct, analyse, and repair simple electrical circuits, using schematic diagrams, working with electrical tools and components, and examining small everyday electrical devices and appliances;
- investigate how electrical devices play a role in the economy of the local community and in the improvement of our standard of living.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- describe the basic components and layout of a simple electrical circuit;
- describe common electrical components that regulate the flow of electricity or that are used as safety mechanisms in circuits (e.g., switches, bimetallic strips, resistors, fuses, ground fault interrupters [GFIs], surge protectors);
- explain the difference between direct current and alternating current, and identify situations in which each is used (e.g., compare the use of direct current in a portable appliance such as a flashlight to the use of alternating current in household appliances);
- analyse, in qualitative terms, the relationship among potential difference, electric current, and resistance in a complete electrical circuit (e.g., determine that the amount of current in an electrical circuit increases as the applied potential difference increases);
- identify the SI units for measuring energy, power, potential difference, current, and resistance;
- describe proper safety procedures necessary for working with electrical systems at home and in the workplace, and identify situations in which electrical circuits can

be fire hazards and dangerous to human life (e.g., describe the potential hazards related to the use of power tools and electric lawnmowers in the rain);

- identify some household appliances that require 110 V AC (e.g., microwave oven, blender) and some that require 220 V AC to operate (e.g., conventional oven, clothes dryer).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- build a simple electrical device, accurately following a clear set of instructions and circuit diagrams (e.g., construct and test a simple electrical device such as a loud-speaker, electric motor);
- design and draw schematic diagrams for electrical circuits with the aid of a computer or by hand;
- safely construct simple electrical circuits from conventional schematic diagrams that include common electrical symbols (e.g., symbols for DC and AC power sources, switches, potentiometers, resistors, bulbs, measurement devices such as ammeters and voltmeters, grounds);

- safely use appropriate tools for constructing electrical circuits (e.g., soldering irons, wire strippers, crimping tools, screwdrivers, and a variety of common connectors);
- identify and appropriately use equipment for measuring potential difference, electrical current, and resistance (e.g., use multimeters and a galvanometer to make various measurements in an electrical circuit; use an oscilloscope to show the characteristics of the electrical current);
- analyse electrical circuits or computer simulations of electrical circuits, identify any faults, and make corrections (e.g., repair a defective small household appliance);
- draw a schematic diagram of the normal electrical circuits in a house, and identify the maximum fused current for each, as prescribed by recent building codes.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- conduct research to collect information on a piece of audio-visual equipment or a major appliance, using consumer reports, and make recommendations for a wise purchase based on cost effectiveness, energy efficiency, quality, and safety of the product;
- devise a household plan for survival in the event of a prolonged public power disruption (e.g., identify alternative sources of energy that are readily available in the community);
- identify and propose solutions to problems related to the environmental impact of the consumption of electrical energy and the disposal of used electrical appliances in Canada (e.g., alternatives to the wholesale discarding of old electrical devices; advantages and disadvantages of the recycling of outdated computer equipment or batteries).

# Micro-organisms

## Overall Expectations

By the end of this course, students will:

- describe the characteristics of some micro-organisms, including ways in which they reproduce and grow in the home, school, and workplace;
- investigate the growth and uses of microbes through laboratory activities;
- analyse the role of microbes in technology, and their impact on society and the environment.

## Specific Expectations

### *Understanding Basic Concepts*

By the end of this course, students will:

- describe the basic characteristics of representative bacteria, protists, viruses, and fungi;
- compare the life cycles of representative bacteria, protists, viruses, and fungi;
- explain the methods of reproduction of representative bacteria, protists, viruses, and fungi;
- describe the anatomy and physiology of representative bacteria, protists, viruses, and fungi;
- describe the nature and function of vaccines;
- describe how bacteria, protists, viruses, and fungi cause diseases in humans and how they are useful to humans.

### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- identify specimens of bacteria, protists, and fungi, using prepared slides and wet mounts;
- formulate scientific questions about practical problems and issues related to micro-organisms (e.g., How do the differences among bacteria, protists, viruses, and fungi affect the ways in which they can be used or controlled?);
- investigate the behaviour of micro-organisms, identifying and controlling major variables and using safe laboratory procedures (e.g., using plating techniques, show how various antibiotics kill bacteria but not other microbes; compare the effectiveness of different mouthwashes in killing bacteria; demonstrate where microbes live in a classroom by taking swabs);
- prepare a product using micro-organisms (e.g., bake leavened bread; make yogurt);\*
- describe various micro-organisms, using the appropriate classification system and nomenclature (e.g., bacteria, protists, viruses, fungi).

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\*These are laboratory products and should *not* be eaten.

***Relating Science to Technology, Society,  
and the Environment***

By the end of this course, students will:

- working cooperatively with team members, compile, display in an appropriate format, and report on information/evidence gathered concerning the benefits and/or costs to society of micro-organisms (e.g., industrial use of microbes, such as in the making of yogurt and in the clean-up of oil spills; microbes and sexually transmitted diseases [STDs]; the potential for biological warfare; drug-resistant bacteria; microbes and the history of hygiene; mouldy-building syndrome; food poisoning; microbes and forensic science; microbes and allergies; the role of microbes in soil and in home composting);
- describe some of the challenges of developing or modifying technologies to control or inhibit the reproduction and growth of micro-organisms (e.g., vaccines to fight viruses that are constantly mutating).

## The Immune System and Human Health

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the human immune system and its capacity to combat disease;
- carry out laboratory studies of micro-organisms that cause disease;
- describe and explain how vaccines and antibiotics are used to assist the immune system in preventing and overcoming disease, and analyse the impact of social and environmental factors on human health.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- explain, in general terms, the cellular and chemical components of the human immune system (e.g., describe how the cell membrane of white blood cells deals with infection; explain how chemicals in the immune system attack foreign or abnormal proteins to protect the body);
- distinguish between communicable and non-communicable diseases;
- describe the role of blood components in controlling pathogens (e.g., clotting factors, white blood cells, antibodies);
- identify the causes, effects, and treatments of common diseases associated with the immune system (e.g., AIDS).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- carry out standard laboratory tests safely to identify substances related to the immune system (e.g., collect and culture different bacteria to measure the effectiveness of antibacterial agents);
- collect data on the immune system, using instruments appropriately and safely (e.g., observe with a microscope prepared slides of various disease-causing microbial organisms, or slides of cellular components of human blood);

- gather, integrate, and interpret information from print and electronic sources on a related health topic, and report the findings (e.g., use current, reliable information sources to find out about the spread of diseases such as AIDS, typhoid, and cholera).

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- explain how specific antibiotics and vaccines can be used to treat or prevent a disease (e.g., measles, rabies, tetanus, smallpox, tuberculosis);
- describe how the overuse and improper use of antibiotics may lead to an increase in bacteria that are resistant to antibiotics;
- analyse ways in which human health has been improved over time as a result of a better understanding of pathogens and genetics and improved sanitary conditions and personal hygiene (e.g., development of a smallpox vaccine by Edward Jenner, or polio vaccine by Jonas Salk; development of public health guidelines for food handling and preparation in restaurants to prevent microbial contamination of the final product).

## Human Impact on the Environment

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the impact of humans on the environment, and assess alternative courses of action to protect the environment;
- evaluate, using data obtained from experiments and from print and electronic sources, the costs and benefits to society and the environment of introducing a particular technology or of protecting or not protecting a specific environment;
- analyse some of the environmental, technological, and social factors that affect the sustainability of the human population on Earth.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- analyse interactions between the environment and human activities (e.g., analyse the interdependence of biotic and abiotic factors in a municipal waste disposal site);
- define population growth and explain the factors that influence it;
- evaluate the correlation between Earth's carrying capacity and the demands on natural resources made by human population growth;
- describe and explain the production, distribution, and use of food resources, using the concept of the energy pyramid;
- explain the importance of biodiversity with respect to the sustainability of life within the biosphere (e.g., the danger of extinction for species that have little genetic variability, or the concern about the diminishing number of species of wheat grown worldwide).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- formulate scientific questions about the effects of various conditions and pollutants on aquatic life (e.g., What are the effects of acidity, temperature, phosphate, oil, etc., on the growth rate of algae?), and plan procedures to investigate the effects;
- conduct and report on an investigation into the effects of pollutants on aquatic life;
- conduct an environmental study (e.g., a study on the effects on the environment of building a power line through a wetland) by gathering, integrating, and analysing information from various sources, and present the results using appropriate formats (e.g., diagrams, charts, tables, graphs);
- propose alternative solutions to a given practical problem (e.g., disposal of community garbage), identify the potential strengths and weaknesses of each solution, and select one as the basis for a plan;

- identify various factors (e.g., scientific data, differing points of view) that influence a decision on a science-related issue (e.g., the decision to take steps to protect wild species of plants, or to preserve a wilderness area; the decision to allow the construction of a golf course, with consideration of such issues as water usage and fertilizer run-off).
- explain the benefits of individual and societal participation in planning, problem solving, decision making, and task completion with respect to environmental issues (e.g., summarize the results of a group project on sustainable agriculture; establish an ecosystem, modify it, and review the results);

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe the historical development of a technology (e.g., crop fertilization), and analyse why and how it was developed and improved over time;
- compare various points of view on an environmental issue (e.g., a proposal to dump garbage in a quarry that is adjacent to a residential area; the sustainability of current agricultural practices);
- analyse the risks and benefits to society, the economy, and the environment of introducing a particular technology (e.g., nuclear power; genetically engineered micro-organisms for pollution clean-up; algae ponds to process sewage).

## Science, Grade 12, University/College Preparation

(SNC4M)

This course enables students, including those who do not intend to pursue science-related programs at the postsecondary level, to further develop their understanding of science and its technological applications. Students will explore a range of topics, including organic products in everyday life; pathogens and disease; energy alternatives and their impact globally; communications systems; and science and contemporary societal issues. Emphasis will be placed on relating these topics to global issues as well as to daily life, and on developing skills in the areas of experimentation, research, critical thinking, and analysis.

**Prerequisite:** Science, Grade 11, University/College Preparation

***Throughout this course, students will:***

- demonstrate an understanding of safety practices consistent with Workplace Hazardous Materials Information System (WHMIS) legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., safely handle organic compounds);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., microscopes, electrical equipment, meters, data loggers);
- demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., design and carry out an experiment to investigate the effectiveness of different antacids);
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., draw and label a diagram of the structure of an organic molecule, identifying its active sites);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., summarize in a chart the various modes of disease transmission);
- communicate the procedures and results of laboratory investigations and research for specific purposes using data tables and laboratory reports (e.g., an investigation of physical and chemical properties of organic products in everyday life; an investigation concerning the application of solar power in battery-driven cars);
- research and evaluate information on a specialized topic in science, and apply it to the world outside the school (e.g., conduct an impact survey on emerging global communication systems; assess the positive and negative aspects of the Human Genome Project);
- select and use appropriate SI units;
- identify and collect information on careers related to the science subject area under study (e.g., TV repair person, VCR technician).

## Organic Products in Everyday Life

### Overall Expectations

By the end of this course, students will:

- describe the properties, benefits, and hazards of representative everyday organic products, and the use of these products in personal daily life, industry, and agriculture;
- investigate the properties of everyday organic products, using appropriate laboratory procedures and equipment safely and accurately, and gathering and integrating information from print and electronic sources;
- analyse the impact on society and the environment of the use of organic products.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define, with examples, terms such as: *soap, detergent, emulsion, emulsifying agent, herbicide, pesticide*;
- compare the properties and structures of inorganic and organic substances (e.g., draw diagrams to show the similarities and differences between inorganic and organic molecules);
- explain the scientific principles involved in the making and use of soaps and detergents (e.g., the principles of bonding related to the making of detergents);
- explain, giving examples, the action of an emulsifying agent (e.g., the effect of dish detergent on fats);
- explain the scientific principles involved in the separation of crude oil into its fractions (e.g., into diesel fuel, gasoline, petroleum jelly);
- describe the properties of chemical fertilizers and pesticides, and their use in agriculture;
- summarize, using scientific principles, the dangers of UV radiation and the role of sunscreens in protecting the skin;

- explain the action of various pharmaceuticals, and their role in personal health-care products (e.g., draw flow charts to show the action and use of aspirin/ASA, antacids, and vitamins in personal health care).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- illustrate the relationship between the structure and function of various organic products by constructing for each a simple model of its molecule and identifying its active parts (e.g., draw and label a diagram of a soap molecule, including its hydrophylic and hydrophobic parts);
- investigate through experimentation the nature of emulsifiers and emulsions (e.g., conduct an experiment to make mayonnaise, or hand cream);
- use laboratory investigation or computer simulation to illustrate the scientific principles upon which fractional distillation of petroleum products is based (e.g., conduct an experiment on the fractional distillation of oil);

- compare, through research in print and electronic sources, the nature and action of chemical and natural fertilizers (e.g., draw a Venn diagram showing the similarities and differences in the action of chemical and natural fertilizers);
- conduct a laboratory investigation into the chemical properties and chemical action of pharmaceutical products (e.g., into the function of antacids or aspirin/ASA).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- analyse the costs and benefits of using organic products (e.g., most pesticides, phosphate detergents), and assess their global impact on the environment;
- identify and describe strategies for pest control other than the use of organic products (e.g., research alternatives to pesticide use in agriculture and the home);
- describe the use and production of representative organic products over time (e.g., cosmetics and other pharmaceutical products).

## Pathogens and Disease

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of micro-organisms, their biological effects, the diseases they cause, and the metabolic and environmental barriers to the spread of disease;
- investigate the nature and growth of representative pathogens, the response of the immune system to them, and the effect on them of various drug therapies and sterilization techniques, using appropriate laboratory procedures and equipment safely and accurately, and gathering and integrating information from print and electronic sources;
- evaluate the measures available for the control of disease, including the role of public policy and the use of health-related technologies and scientific knowledge.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define, with examples when appropriate, such terms as: *micro-organism, pathogen, parasite, disease, epidemiology, pathogenesis, vector*;
- describe the characteristics and reproductive cycles of representative pathogens (e.g., lysogenic cycle, lytic cycle, infectious cycle of malaria);
- describe the modes of transmission of diseases, including those that are insect-borne (e.g., malaria, encephalitis), airborne (e.g., influenza, tuberculosis), water-borne (e.g., cholera, poliomyelitis), sexually transmitted (STDs; e.g., AIDS), and food-borne (e.g., mad cow disease, trichinosis, food poisoning);
- describe and explain the immune response of the body as a natural defence against infection (e.g., the immune response to salmonella food poisoning, or trichinosis);
- describe the use of vaccines, antibiotics, antiseptics, and other drug therapies in the control of pathogenesis;
- describe non-medicinal ways to protect oneself from contracting pathogenic diseases (e.g., aseptic techniques, personal hygiene).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- investigate experimentally, using aseptic techniques, the characteristics and growth of non-pathogenic bacteria (e.g., conduct an experiment to compare different types of bacteria, using commercially prepared slides);
- present a comparative analysis, based on their own research, of the various modes of transmission of pathogens;
- research and report on the nature of the immune response in the human body (e.g., summarize the steps in the human immune response to a typical pathogen);
- identify, through laboratory investigation, the effects of various drug therapies on pathogenesis (e.g., ask a testable question, propose a hypothesis, and conduct an experiment related to the effect of mouthwash or penicillin on the growth of bacteria);
- demonstrate, through laboratory investigation, the effect on pathogenesis of the use of sterile techniques (e.g., the effect on pathogenesis of the pasteurization of dairy products).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe some of the means used by agencies and governments to control the spread of disease, both locally and globally;
- evaluate the impact on an individual and on society of the misuse of antibiotics in the control of infection (e.g., chart the cause-and-effect relationships between the use of antibiotics and vaccines and the development of viral mutations and resistant strains of bacteria);
- research and explain the impact on disease control of technological advances in food preparation and preservation (e.g., the impact of freezing, pasteurization, radiation, and canning on food marketing);
- describe aseptic techniques used in the workplace and explain their importance (e.g., the techniques used to prevent food poisoning or the spread of disease in a food preparation facility or a restaurant);
- research and describe the impact on populations of the use of new technologies to control disease (e.g., gather and integrate information on community demographics and rates of infant survival to illustrate the effect over time of new vaccines and antibiotics).

## Energy Alternatives and Global Impact

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the scientific principles of energy production from conventional and alternative sources;
- compare the practical value of a variety of alternative energy sources, through investigation and cost-benefit analysis;
- assess conventional and alternative energy sources in terms of their ability to satisfy societal demand and of their environmental impact.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define, with examples when appropriate, terms such as: *joule, rad, watt, fission, fusion, chain reaction, activation energy, renewable/non-renewable resources, conventional/alternative energy sources*;
- compare and contrast conventional and alternative energy sources with respect to criteria such as availability, renewability, cost, and environmental impact (e.g., draw a Venn diagram showing similarities and differences between the use of fossil fuels and geothermal energy);
- describe technologies created in response to dwindling non-renewable energy resources (e.g., windmills, solar panels, electric cars);
- compare the relative amounts of energy released in various physical, chemical, and nuclear transformations (e.g., create charts to compare the energy released in condensation of water vapour, combustion of gasoline, and splitting of the atom);
- describe the scientific principles of fission and a chain reaction and their applications in nuclear generating stations (e.g., the scientific principles applied in the CANDU reactor);
- compare and contrast nuclear fission and nuclear fusion according to such criteria as feasibility, costs, and energy efficiencies.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- analyse data to determine which human activities consume the most energy, and how changing patterns of behaviour can reduce the total amount of energy consumed;
- gather and analyse data, experimentally or through research, to evaluate alternative and emerging technologies as examples of responsible energy use (e.g., technologies related to wind power, solar power, electric cars, ethanol fuel, or the fermentation of waste products);
- evaluate arguments for the use of nuclear technology, based on research into its advantages and disadvantages (e.g., production of greenhouse gases from fossil fuels is reduced but production of nuclear waste is increased);
- present an argument, based on research and scientific analysis, for the use of an alternative energy system (e.g., a solar cooker, or a solar collector);
- design a system that uses an alternative energy source (e.g., design, build, and test a working model of a wind generator, or a solar-powered car).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- identify, based on information integrated from print and electronic sources, short- and long-term environmental effects of by-products from nuclear generating stations;
- identify new energy applications inspired by traditional energy sources (e.g., battery-operated cars including those powered by fuel cells);
- evaluate the environmental impact of a specific alternative source of energy (e.g., conduct an environmental impact survey that covers such issues as costs and waste production/management);
- analyse the costs and benefits to society of alternative energy systems, and assess the impact of their use on a global scale (e.g., wind generators, or tidal power plants);
- evaluate the suitability of alternative energy sources, using research into the regional availability of natural resources in Canada (e.g., draw a correlation map for Canada showing regional energy systems and the distribution of natural resources, including water, fossil fuels, heat sinks, and wind and tides).

## Communications Systems

### Overall Expectations

By the end of this course, students will:

- explain the fundamental scientific principles that are applied in modern communications systems;
- explain, on the basis of their findings from laboratory investigations, how modern communications systems function;
- evaluate the advantages and disadvantages of modern communications systems, for both the individual and society.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- define, with examples when appropriate, terms such as: *wave, wavelength, frequency, semi-conductor, electromagnetic spectrum, fibre optic cabling*;
- identify and describe the technologies involved in various communications systems (e.g., technologies involved in the Global Positioning System [GPS], or the Internet);
- explain the fundamental scientific principles related to the use of a communications technology (e.g., fibre optics in a communications system);
- explain, based on information from print and electronic sources, how electromagnetic radiation, as a form of energy, is produced and transmitted (e.g., radio waves);
- identify and describe (e.g., outline, in a concept diagram) the properties and applications of the various regions of the electromagnetic spectrum;
- identify and describe the applications of the electromagnetic spectrum in communications systems (e.g., radio, television, telephone, radar, satellites, fibre optics, or converters);

- identify and explain the application of semi-conductors in communications systems (e.g., the use of semi-conductors in computers and graphic projection devices);
- explain the energy transformations that take place to permit the transmission and reception of signals in communications systems;
- describe how sound energy is received, analysed, and reproduced electronically (e.g., energy transformations in the functioning of a microphone).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- explain and analyse scientific principles related to communications systems (e.g., the Internet) using appropriate terminology;
- describe and follow procedures for the safe and accurate use of electrical equipment as outlined in the Occupational Health and Safety Act and the Fire Code (e.g., describe the safety measures followed in an experiment involving the use of electrical equipment);

- design, construct, and test a simple device that transforms energy (e.g., sound, light) from one form to another (e.g., design, construct, and test a prototype of a photovoltaic cell, loudspeaker, or doorbell);
- identify and describe, through experimentation, how common communications equipment functions (e.g., conduct an experiment related to the design and functioning of a telephone or radio).
- assess the impact of new communications systems (e.g., the Internet, surveillance technologies) on the privacy of individuals and communities, focusing on risks and benefits;
- forecast and assess the future effects of the use of new communications systems, locally and globally (e.g., the effects on time management, networking, and world trade).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- assess the impact of new communications systems (e.g., cell phones) on individual lifestyles and on home and workplace environments;

## Science and Contemporary Societal Issues

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of how scientific knowledge has evolved and continues to evolve through scientific discoveries, past and present;
- assess the strengths and limitations of scientific knowledge and procedures as means for resolving contemporary societal issues;
- evaluate the social and environmental implications and technological applications of contemporary scientific discoveries, and consider different cultural and societal perspectives on the discoveries.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- formulate definitions of scientific terms such as: *principle, law, theory, fact, observation, concept, inference, causality*;
- explain how scientific knowledge evolves as new evidence comes to light and as theories are modified (e.g., draw a timeline chart to outline the historical relationship between experimental evidence, scientific inference, and accepted theory);
- explain how evidence, theories, and paradigms contributed to a recent scientific discovery (e.g., write a report on James Watson and Francis Crick’s work in establishing the physical structure of DNA, describing the relationship between scientific ways of thinking, experimental evidence, and the nature of the resulting theory);
- explain how a scientific discovery can lead to a paradigm shift in responses to a problem (e.g., conduct a media search on how the discovery of stomach bacteria changed the treatment of “lifestyle” diseases such as stomach ulcers);
- identify technologies that have been developed as a result of a scientific discovery (e.g., the standard tungsten incandescent bulb or the tungsten-halogen bulb following research into high-resistance filaments);

- identify examples of the growth of scientific knowledge as a result of a technological invention (e.g., compile and display recent data on distant galaxies obtained by the Hubble Space Telescope).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- demonstrate, through laboratory investigation, case study, or computer simulation, the habits of mind appropriate to scientific investigation, including objectivity, tentativeness, accuracy, and consistency (e.g., collect, record, and analyse data related to a case study involving the possible impact of the physical environment on genetic expression in humans);
- analyse and interpret, through laboratory investigation, case study, or computer simulation, scientific evidence relevant to a contemporary societal issue (e.g., ask a testable question and propose a hypothesis related to the cause-and-effect relationship between water chlorination and formation of organo-chlorides);
- research and defend, from a scientific perspective, a particular view of a contemporary societal issue as reported in the media (e.g., summarize the point of

- view presented in a magazine article on government support for hepatitis sufferers, and assess its merit from a scientific perspective);
- evaluate, through interview and research, differing cultural perspectives on a contemporary subject or issue to which science is also relevant (e.g., a First Nations' perspective on maintaining natural balance through the use of alternative medicines).
- analyse ways in which societal needs or demands influence scientific and technological endeavours (e.g., relate levels of funding for AIDS research over time to societal influences);
- describe the processes by which the private and public sectors have cooperated to establish and fund some Canadian research projects in science and technology.

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- explain how a particular technological application of a scientific discovery is perceived by various interest groups in the community (e.g., present the views of different groups on the risks and benefits of using bovine growth hormone in milk production);
- assess the possible positive and negative effects of a scientific discovery on society and the environment (e.g., positive and negative aspects of the Human Genome Project);

## Science, Grade 12, Workplace Preparation

(SNC4E)

This course provides students with the science-related knowledge and skills they need to help them make informed decisions in the workplace and in their personal lives. Students will explore a range of topics, including chemistry at home and at work; communications technology; medical technology; gardening, horticulture, landscaping, and forestry; and alternative life-sustaining environments. Emphasis is placed on relating these topics directly to students' experiences both in the world of work and in daily life.

**Prerequisite:** Science, Grade 11, Workplace Preparation

***Throughout this course, students will:***

- demonstrate an understanding of safety practices consistent with Workplace Hazardous Materials Information System (WHMIS) legislation by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., identify the appropriate procedures for storing and disposing of flammable solvents, and for handling acids, bases, and non-aqueous solutions of toxic substances);
- select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., frequency meter, oscilloscope, dialysis tubing, data loggers);
- demonstrate the skills required to plan and carry out investigations, using laboratory equipment safely, effectively, and accurately (e.g., conduct an experiment to investigate the physical and chemical properties of common synthetic polymers);
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., express as an equation the relationship among variables for a vibrating string pendulum);
- locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites (e.g., compile a table of energy sources and their uses; prepare a report on waste disposal in alternative life-sustaining environments);
- compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams;
- communicate the procedures and results of laboratory investigations and research for specific purposes using data tables and laboratory reports (e.g., prepare a laboratory report on the dialysis of nutrients);
- select and use appropriate SI units;
- identify and collect information on science- and technology-based careers related to the subject area under study (e.g., horticulturalist, medical technician, forester).

## Chemistry at Home and Work

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the structure, properties, and reactions of common organic materials encountered in the home and workplace;
- investigate the properties of some organic substances, and safely prepare a number of common organic products and emulsions;
- describe the importance of common organic substances used in the home and workplace, and demonstrate an awareness of some of the health, safety, economic, and environmental issues related to the use of these substances.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- illustrate and explain the formation of covalent bonds, especially those involving H, C, N, and O;
- explain how the hydrophobic, hydrophilic, or amphiphilic character of organic molecules is related to the presence of O, N, or ions in the molecule;
- predict, on the basis of the affinity of substances with similar chemical properties, the solubility of common organic substances in aqueous and non-aqueous solvents (e.g., polar and ionic substances are generally soluble in polar solvents; non-polar substances are generally soluble in non-polar solvents);
- explain the behaviour of emulsifying agents (e.g., soap, eggs);
- write word equations for simple condensation and hydrolysis reactions;
- describe the process of polymerization in terms of one or two simple molecules that are repetitively connected into a very large structure (e.g., ethene to polyethylene; glucose to starch; adipic acid and diamino-hexane to nylon).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- select and use appropriate vocabulary, including correct chemical terminology (e.g., *condensation*, *hydrolysis*, *miscible*, *emulsion*, *hydrophilic*, *hydrophobic*, *amphiphilic*), to communicate scientific ideas, procedures, and results;
- determine, through their own observations, the miscibility of a variety of organic liquids with each other and with water;
- plan and carry out safely laboratory investigations of emulsions (e.g., determine the effects on the stability of emulsions of emulsion-forming and emulsion-breaking agents such as soap, salt, and eggs);
- carry out experiments to compare the relative quantities of soap and detergent required to form emulsions in hard and soft water;
- safely prepare some common organic products by the processes of emulsion, condensation, hydrolysis, and polymerization (e.g., cold cream, mayonnaise, aspirin/ASA, or soap);

- carry out experiments safely to identify some of the physical and chemical properties of common synthetic polymers (e.g., determine the fusibility and aqueous and non-aqueous solubility of polyethylene, styrofoam, nylon, polyester, or melamine);
- test and compare the properties of naturally occurring polymers, such as cotton and silk, with their synthetic counterparts, rayon and nylon.
- prepare, and present to classmates, a report on the social, environmental, and economic consequences of the use and discarding of organic products (e.g., common addition plastic, copolymer, thermosetting plastic, or vulcanized products; natural and synthetic fabrics).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- research an important application of condensation, hydrolysis, or emulsification processes, and report on their findings using an appropriate format (e.g., the industrial or home preparation of an emulsified food or cosmetic product, such as salad dressing, skin cream, or lipstick; the important role of condensation and hydrolysis reactions in the synthesis and digestion of major molecules in living organisms);

## Communications: Sounds and Pictures

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the basic operating principles of entertainment and communications devices that are commonly found in the home and the workplace;
- carry out investigations concerning the scientific concepts involved in communications technology, and examine and operate some common communications devices;
- research and evaluate the role played by the many different kinds of technological devices used for communication, and their impact on the way we conduct our lives at home and at work.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- describe and illustrate the properties of a vibrating object, and explain how vibrating objects (e.g., drums, guitar strings, wave-making machines in theme parks) produce waves;
- explain in qualitative terms how frequency, amplitude, and wave shape affect the pitch, intensity, and quality of notes produced by musical instruments;
- describe and compare the properties of transverse and longitudinal waves;
- explain how different forms of energy can be transformed into, and transmitted as, waves (e.g., mechanical energy to sound energy; electrical energy to electromagnetic energy);
- describe and explain in qualitative terms what happens when waves interact (interfere) with one another (e.g., production of beats, or of voice patterns on an oscilloscope);
- explain, in terms of the properties of waves, how energy from communications devices is transmitted, reflected, and absorbed by different kinds of matter (e.g., how devices such as motion detectors, cordless telephones, and television remote controls work);
- describe in qualitative terms, with examples, the effects produced by the refraction and total internal reflection of visible light waves as they pass through different transparent media, and explain how these effects are applied in various entertainment and communications devices (e.g., the function of lenses and prisms in a television camera);
- examine and describe the operation of transducers that carry out the energy transformations in common communications equipment (e.g., explain how transducers work in microphones, photocells, aerials and antennas, earphones, loudspeakers, product code readers, or television screens).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- formulate scientific questions about waves (e.g., What are the properties of longitudinal and transverse waves? What happens when two identical periodic waves traveling in opposite directions interact?);
- determine experimentally the relationships among the major variables for a vibrating object (e.g., carry out an investigation to determine the relationships among the length of a string pendulum and the frequency and period of its vibration);

- estimate the value of some wave-related quantities (e.g., the period and frequency of a string pendulum; the note produced by a musical instrument; the intensity of a sound in decibels; the distance from an observer to the location of a bolt of lightning);
- use instruments and communications equipment safely, effectively, and accurately to collect and present data (e.g., instruments/equipment such as a stopwatch, frequency meter, oscilloscope, tape recorder, VCR, or sound data logger);
- conduct investigations to analyse and explain the production of sound by a vibrating object (e.g., how different string or wind instruments produce notes);
- construct and test a prototype of a communications device, and resolve problems as they arise (e.g., work cooperatively with team members to construct and test a simple loudspeaker; construct, test, and demonstrate a simple audio amplifier).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe the historical development of a significant product of communications technology (e.g., telephone, radio, television, cell phone, communications satellite);
- describe, using scientific principles, the functioning of common domestic and industrial communications technologies (e.g., cell phone, satellite system, ATM, store check-out system);
- describe some Canadian contributions to the field of communications technology (e.g., the work of Alexander Graham Bell or Reginald A. Fessenden);
- describe the impact of developments in communications technology on the way we work and on our social environment (e.g., telecommuting, flexible workplace, global communications).

## Medical Technology

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the role of genetics and of various technologies, including biotechnology, in the diagnosis and treatment of human illness;
- gather and analyse scientific data using techniques similar to those employed in medical testing and diagnosis;
- evaluate, based on representative examples, ways in which science and technology have influenced the diagnosis and treatment of human illness, and work collaboratively to analyse an issue related to biotechnology.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- demonstrate an understanding of terms related to medical and reproductive technology (e.g., *cloning, genetic engineering, heredity, karyotype, pedigree*);
- explain the use of technology for diagnostic medical applications (e.g., the use of lasers, ultrasound, computer axial tomography [CAT] scans, doppler scans, X-rays, magnetic resonance imaging [MRI], fibre optics);
- describe the use of technology for bio-medical repair (e.g., prosthetics, artificial organs, plastic surgery);
- describe and illustrate the role of chromosomes in the transmission of hereditary information from one cell to another, and explain how genetic disorders may occur;
- describe the use of karyotypes and pedigrees as diagnostic tools for determining genetic diseases (e.g., analyse the karyotypes or pedigree from the case study of a person having Down syndrome);
- describe the basic scientific and technological principles involved in genetic engineering (e.g., compile and display information on bacterial production of human insulin, or DNA fingerprinting).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- conduct a laboratory experiment that simulates a process occurring in a medical apparatus (e.g., simulate the dialysis of nutrients by collecting and accurately recording data in an experiment on the diffusion of glucose through an artificial membrane);
- state a hypothesis and make predictions, based on available evidence and background information, concerning a particular medical problem (e.g., analyse a pedigree or karyotype for a genetic disorder).

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- provide examples of how science and technology have influenced the diagnosis and treatment of human illness, and have made medical technology an integral part of our lives (e.g., the role of X-rays, ultrasound, wheelchairs, artificial organs, prosthetics, reproductive technologies, laser surgery, computer axial tomography [CAT] scans);

- work as a member of a team to research, develop, and present material on an issue related to modern genetic technology (e.g., the ethical issues involved in the cloning of animals or humans, the use of genetic evidence in court, the insertion of animal genes in plants, the question of who owns genetic information).

## Gardening, Horticulture, Landscaping, and Forestry

### Overall Expectations

By the end of this course, students will:

- demonstrate an understanding of the conditions required for plant growth, and of the techniques used in gardening, horticulture, landscaping, and forestry;
- investigate experimentally the effect of various conditions on the growth of plants, and demonstrate skills in the use of tools and techniques associated with either gardening, horticulture, or landscaping;
- demonstrate an understanding of the importance of cultivated and wild plants to society, the economy, and the environment.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- identify the general conditions necessary for healthy plant growth (e.g., describe optimal growth conditions for a specific type of plant);
- describe the basic steps in growing plants from seed (e.g., collecting seeds, sowing, providing conditions favourable to germination, and thinning);
- identify evidence of plant problems (e.g., wilting, off-colour leaves, leaf and bud drop, root and stem rot, and the visible presence of pests);
- describe, with examples, the differences among common house and garden plants and native trees that have been classified according to normal life cycles (e.g., annuals, biennials, and perennials) or method of culture (e.g., potting, seeding, making cuttings, transplanting);
- describe different methods of gardening and how each controls conditions of growth (e.g., organic gardening, greenhouse gardening, and hydroponics);
- describe some common forest-management practices (e.g., clear-cutting, sustainable forestry based on selective cutting, pruning);

- describe the design elements (e.g., colour, texture, balance, contrast, harmony, repetition) and the materials (e.g., plant materials, construction materials, soil, water) used in landscaping.

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- design and conduct an experiment to determine the effect of various environmental conditions (e.g., temperature, light, fertilizers, plant hormones) on plant growth;
- carry out soil tests to determine optimum conditions for the growth of plants (e.g., determine experimentally the correct pH value of the soil, or the optimum percentages of nitrogen, phosphorus, and potassium for particular plants);
- investigate the various methods used to control the conditions of growth for plants (e.g., describe how conditions are controlled in a greenhouse, tree nursery, or hydroponic installation);
- propagate and grow plant crops for use or sale, and keep records of their growth (e.g., grow vegetables or bedding plants from seed and transplant them to the home garden; grow trees from seeds, or plant seedlings on the school grounds);

- identify the features of a good landscape architecture site, and prepare a plan to scale for an outdoor garden (e.g., in the school grounds, or a public park).

***Relating Science to Technology, Society, and the Environment***

By the end of this course, students will:

- describe the diversity of environments that must be maintained in order to provide habitats for a wide variety of plants (e.g., make a list of the environmental conditions – soil composition, light conditions, landscaping – required for particular types of plants);
- demonstrate an understanding of the variety of ways in which human populations depend on healthy plant populations (e.g., for food, clothing fibres, fuel, structural materials);
- demonstrate an understanding of the role of forests as essential habitats for other plants and animals, including threatened and endangered species (e.g., describe the environmental, economic, and social effects of various types of forestry practice, such as clear-cut forestry or sustainable forestry using selective cutting);
- analyse the social, economic, and environmental factors that determine the different approaches and methods required in gardening, horticulture, landscaping, and forestry (e.g., explain and evaluate the problems of monoculture and the environmental need for biodiversity in horticulture; or participate in a group debate concerning the economic benefits and costs of sustainable forestry).

## Alternative Environments

### Overall Expectations

By the end of this course, students will:

- demonstrate a knowledge of the inputs, outputs, and interactions involved in maintaining an alternative life-sustaining environment;
- analyse major variables that affect the various inputs, outputs, and interactions involved in maintaining an alternative life-sustaining environment;
- demonstrate an understanding of what would be required to equip and operate an alternative environment capable of supporting human life, and compare its sustainability to that of our normal planetary environment.

### Specific Expectations

#### *Understanding Basic Concepts*

By the end of this course, students will:

- identify the systems required to sustain human life in an environment (e.g., biotic and abiotic factors in our ecosystem);
- describe the inputs of food, energy, air, and water needed to maintain an alternative life-sustaining environment;
- identify the components of an alternative life-sustaining environment (e.g., source[s] of energy, atmosphere, means for recycling or disposing of waste), and describe how they must interact to be successful;
- describe the outputs of an alternative life-sustaining environment, and the systems required to handle them (e.g., air filtration systems);
- describe the difficulties facing humans living in a weightless self-supporting environment (e.g., the difficulties of reducing human waste).

#### *Developing Skills of Inquiry and Communication*

By the end of this course, students will:

- determine, through experimentation, the different factors affecting a controlled micro-environment (e.g., the factors affecting a yeast suspension, a fruit-fly culture, an aquarium, or a terrarium);

- formulate scientific questions about the nature of alternative life-sustaining environments (e.g., What becomes of the waste produced in an alternative environment?);
- use flow charts to diagram the inputs, outputs, and interactions of the various life-sustaining components of an alternative environment (e.g., energy flow, waste disposal, atmosphere).

#### *Relating Science to Technology, Society, and the Environment*

By the end of this course, students will:

- analyse, using knowledge of the requirements for sustainability, existing alternative life-sustaining environments (e.g., International Space Station, Earth-based self-sustaining biodome experiments, nuclear submarines, off-shore oil rigs), and make suggestions for their improvement or development;
- assess a Canadian contribution to the development of alternative life-sustaining environments (e.g., gather, integrate, and analyse information about the Montreal Biodome);

- relate what they have learned about sustaining life in alternative environments to the processes through which our own natural environment sustains life (e.g., relate the mechanical processes of an air purification system to the natural process of air purification by trees);
- analyse the costs and benefits to society, the economy, and the environment of constructing and operating an alternative environment capable of supporting human life (e.g., write a brief essay on the potential economic benefits of maintaining an alternative life-sustaining environment such as the International Space Station).



## Some Considerations for Program Planning in Science

Teachers who are planning a program in science must take into account considerations in a number of important areas. Essential information that pertains to all disciplines is provided in *The Ontario Curriculum, Grades 9 to 12: Program Planning and Assessment, 2000*. The areas of concern to all teachers that are outlined there include the following:

- types of secondary school courses
- education for exceptional students
- the role of technology in the curriculum
- English as a second language (ESL) and English literacy development (ELD)
- career education
- cooperative education and other workplace experiences
- health and safety

Considerations relating to the areas listed above that have particular relevance for program planning in science are noted here.

***Education for Exceptional Students.*** The Education Act and regulations made under the act require school boards to provide exceptional students with special education programs and services that are appropriate for their needs.

An Individual Education Plan (IEP) must be developed and maintained for each student who is identified as exceptional by an Identification, Placement, and Review Committee (IPRC). The IEP must outline, as appropriate, any modified or alternative curriculum expectations and any accommodations (i.e., the specialized support and services) that are required to meet the student's needs. The IEP must also identify the methods by which the student's progress will be reviewed. For exceptional students who are fourteen years of age or older and who are not identified solely as gifted, the IEP must contain a plan to help them make the transition to postsecondary education, apprenticeship programs, or the workplace, and to help them live as independently as possible in the community.

An IEP may be prepared for students with special needs who are receiving special education programs and/or services but who have not been identified as exceptional by an IPRC.

In planning programs in science, teachers should recognize that exceptional students may require focused and specialized directions, as well as advance instruction and additional practice in the use of equipment. Issues relating to safety in the laboratory and to students' ability to read laboratory manuals and use laboratory equipment must be addressed before students can be expected to participate effectively. Changes to teaching materials may involve the use of large-print activity sheets, the highlighting of key points on print materials, and the use of alternative texts at a suitable reading level. Assessment strategies should allow students to demonstrate their understanding of scientific concepts in a variety of ways, such as by performing experiments, creating displays and models, and tape-recording observations. Computer programs may be used to provide opportunities for scientific practice and for recording results.

In science, exceptional students may need a variety of modifications both to the program itself and to the learning environment. These may include the following:

- facilities that allow for the mobility of students with physical impairments
- modifications to programs for students with learning disabilities who may require more hands-on opportunities for learning
- program adaptations for students who are deemed gifted
- visual signs related to safety issues
- assessment and evaluation strategies that accommodate a variety of learning styles and needs

***The Role of Technology in the Curriculum.*** Students will be expected to use computer programs that have been developed for use in science. These include programs for simulations, multimedia resources, databases, and computer-assisted learning modules. Students will also be expected to use computer programs to help them develop more general skills, such as skills in writing, problem solving, and researching.

In science, students gain “hands-on” experience with technology in the laboratory. Apparatus as diverse as digital balances and volumetric apparatus in chemistry, microscopes and Petri dishes in biology, and air tables and ammeters in physics provide the kinesthetic learner with unique learning experiences. Computers can be used in science to support laboratory investigations; for example, electronic probes can be used to monitor variables such as temperature, pH, and velocity. Computer programs can also be used to process class data and to simulate environmental or industrial scenarios, or animal dissections. Care must be taken, however, to ensure that computer-assisted laboratory programs are not used in situations where students’ own technical skills should be developed, such as in analysing and graphing data.

The Internet is a particularly valuable source of scientific information that students should be taught to access. In addition, some programs enable students to conduct scientific investigations and then use the tools of electronic communication to compare their results and analyses with those of students in other parts of Canada and around the world.

***English As a Second Language and English Literacy Development (ESL/ELD).*** Science presents particular linguistic challenges to all students because of its specialized terminology and language structures. Science teachers who have ESL/ELD students in their classes should respond to the special needs of these students, providing support with respect to their comprehension and use of language in a scientific context.

***Career Education.*** Ongoing scientific discoveries, coupled with rapidly evolving technologies, have resulted in an exciting environment in which creativity and innovation thrive, bringing about new career opportunities. Today’s employers seek candidates with strong critical-thinking and problem-solving skills and the ability to work cooperatively in a team – traits that are developed through participation in the science program. Through science courses, students will develop, for example, the ability to identify issues, conduct research, carry out experiments, solve problems, present results, and work on projects both independently and in a team. The science program should be designed to give students an opportunity to explore science-related careers.

***Cooperative Education and Other Workplace Experiences.*** Through participation in science-related learning activities in commercial, industrial, government, or academic laboratory settings, students can experience the application of knowledge and skills in specific areas of science in settings outside the school. These experiences give students the opportunity to practise and develop their own skills in problem solving, critical thinking, teamwork, and the safe and accurate use of scientific procedures and tools. In addition, they provide students with a clearer sense of the nature of careers in science-related fields. It is important for students to understand that the study of science can help them develop their own interests and to contribute in practical ways to their community.

***Health and Safety.*** Teachers are responsible for ensuring the safety of students during classroom activities and for teaching students to assume responsibility for their own and others' safety. They must model safe practices and communicate safety expectations to students in accordance with school board and ministry policies. This concern for safety in science requires that students demonstrate:

- knowledge about the materials, tools, processes, and procedures used in science;
- skill in performing tasks in the laboratory;
- knowledge about health and safety concerns and about the care of living things (plants and animals) that are brought into the classroom;
- concern for the health and safety of themselves and others.

Students demonstrate the knowledge, skills, and habits of mind required for safe involvement in science when they, for example:

- maintain a well-organized and uncluttered work space;
- carefully follow the instructions and example of the teacher;
- identify possible health and safety concerns;
- follow established safety procedures;
- suggest and implement appropriate safety procedures in new situations;
- comply with Workplace Hazardous Materials Information System (WHMIS) legislation.

## The Achievement Chart for Science

The achievement chart that follows identifies four categories of knowledge and skills in science – Knowledge/Understanding, Inquiry, Communication, and Making Connections. These categories encompass all the curriculum expectations in courses in the discipline. For each of the category statements in the left-hand column, the levels of student achievement are described. (Detailed information on the achievement levels and on assessment, evaluation, and reporting policy and its implementation is provided in *The Ontario Curriculum, Grades 9 to 12: Program Planning and Assessment, 2000*.)

The achievement chart is meant to guide teachers in:

- planning instruction and learning activities that will lead to the achievement of the curriculum expectations in a course;
- planning assessment strategies that will accurately assess students' achievement of the curriculum expectations;
- selecting samples of student work that provide evidence of achievement at particular levels;
- providing descriptive feedback to students on their current achievement and suggesting strategies for improvement;
- determining, towards the end of a course, the student's most consistent level of achievement of the curriculum expectations as reflected in his or her course work;
- devising a method of final evaluation;
- assigning a final grade.

The achievement chart can guide students in:

- assessing their own learning;
- planning strategies for improvement, with the help of their teachers.

The achievement chart provides a standard province-wide method for teachers to use in assessing and evaluating their students' achievement. A variety of materials is being made available to assist teachers in improving their assessment methods and strategies and, hence, their assessment of student achievement.

The ministry is providing the following materials to school boards for distribution to teachers:

- a standard provincial report card, with an accompanying guide
- instructional planning materials
- assessment videos
- training materials
- an electronic curriculum planner

When planning courses and assessment, teachers should review the required curriculum expectations and link them to the categories to which they relate. They should ensure that all the expectations are accounted for in instruction, and that achievement of the expectations is assessed within the appropriate categories. The descriptions of the levels of achievement given in the chart should be used to identify the level at which the student has achieved the expectations. Students should be given numerous and varied opportunities to demonstrate their achievement of the expectations across the four categories. Teachers may find it useful to provide students with examples of work at the different levels of achievement.

The descriptions of achievement at level 3 reflect the provincial standard for student achievement. A complete picture of overall achievement at level 3 in a course in science can be constructed by reading from top to bottom in the column of the achievement chart headed “70–79% (Level 3)”.

**Achievement Chart – Grades 11 and 12, Science**

<b>Categories</b>	<b>50–59% (Level 1)</b>	<b>60–69% (Level 2)</b>	<b>70–79% (Level 3)</b>	<b>80–100% (Level 4)</b>
<b>Knowledge/ Understanding</b>	<b>The student:</b>			
– understanding of concepts, principles, laws, and theories (e.g., identifying assumptions; eliminating misconceptions; providing explanations)	– demonstrates limited understanding of concepts, principles, laws, and theories	– demonstrates some understanding of concepts, principles, laws, and theories	– demonstrates considerable understanding of concepts, principles, laws, and theories	– demonstrates thorough understanding of concepts, principles, laws, and theories
– knowledge of facts and terms	– demonstrates limited knowledge of facts and terms	– demonstrates some knowledge of facts and terms	– demonstrates considerable knowledge of facts and terms	– demonstrates thorough knowledge of facts and terms
– transfer of concepts to new contexts	– infrequently transfers simple concepts to new contexts	– sometimes transfers simple concepts to new contexts	– usually transfers simple and some complex concepts to new contexts	– routinely transfers complex concepts to new contexts
– understanding of relationships between concepts	– demonstrates limited understanding of relationships between concepts	– demonstrates some understanding of relationships between concepts	– demonstrates considerable understanding of relationships between concepts	– demonstrates thorough and insightful understanding of relationships between concepts
<b>Inquiry</b>	<b>The student:</b>			
– application of the skills and strategies of scientific inquiry (e.g., initiating and planning, performing and recording, analysing and interpreting, problem solving)	– applies few of the skills and strategies of scientific inquiry	– applies some of the skills and strategies of scientific inquiry	– applies most of the skills and strategies of scientific inquiry	– applies all or almost all of the skills and strategies of scientific inquiry
– application of technical skills and procedures (e.g., procedures in using microscopes)	– applies technical skills and procedures with limited competence	– applies technical skills and procedures with moderate competence	– applies technical skills and procedures with considerable competence	– applies technical skills and procedures with a high degree of competence
– use of tools, equipment, and materials	– uses tools, equipment, and materials safely and correctly only with supervision	– uses tools, equipment, and materials safely and correctly with some supervision	– uses tools, equipment, and materials safely and correctly	– demonstrates and promotes the safe and correct use of tools, equipment, and materials

Categories	50–59% (Level 1)	60–69% (Level 2)	70–79% (Level 3)	80–100% (Level 4)
<b>Communication</b>	<b>The student:</b>			
– communication of information and ideas	– communicates information and ideas with limited clarity and precision	– communicates information and ideas with moderate clarity and precision	– communicates information and ideas with considerable clarity and precision	– communicates information and ideas with a high degree of clarity and precision
– use of scientific terminology, symbols, conventions, and standard (SI) units	– uses scientific terminology, symbols, conventions, and SI units with limited accuracy and effectiveness	– uses scientific terminology, symbols, conventions, and SI units with some accuracy and effectiveness	– uses scientific terminology, symbols, conventions, and SI units with considerable accuracy and effectiveness	– uses scientific terminology, symbols, conventions, and SI units with a high degree of accuracy and effectiveness
– communication for different audiences and purposes	– communicates with a limited sense of audience and purpose	– communicates with some sense of audience and purpose	– communicates with a clear sense of audience and purpose	– communicates with a strong sense of audience and purpose
– use of various forms of communication (e.g., reports, essays)	– demonstrates limited command of the various forms	– demonstrates moderate command of the various forms	– demonstrates considerable command of the various forms	– demonstrates extensive command of the various forms
– use of information technology for scientific purposes (e.g., specialized databases)	– uses technology with limited appropriateness and effectiveness	– uses technology with moderate appropriateness and effectiveness	– uses appropriate technology with considerable effectiveness	– uses appropriate technology with a high degree of effectiveness
<b>Making Connections</b>	<b>The student:</b>			
– understanding of connections among science, technology, society, and the environment	– shows limited understanding of connections in familiar contexts	– shows some understanding of connections in familiar contexts	– shows considerable understanding of connections in familiar and some unfamiliar contexts	– shows thorough understanding of connections in familiar and unfamiliar contexts
– analysis of social and economic issues involving science and technology	– analyses social and economic issues with limited effectiveness	– analyses social and economic issues with moderate effectiveness	– analyses social and economic issues with considerable effectiveness	– analyses complex social and economic issues with a high degree of effectiveness
– assessment of impacts of science and technology on the environment	– assesses environmental impacts with limited effectiveness	– assesses environmental impacts with moderate effectiveness	– assesses environmental impacts with considerable effectiveness	– assesses environmental impacts with a high degree of effectiveness
– proposing of courses of practical action in relation to science- and technology-based problems	– extends analyses of familiar problems into courses of practical action with limited effectiveness	– extends analyses of familiar problems into courses of practical action with moderate effectiveness	– extends analyses of familiar problems into courses of practical action with considerable effectiveness	– extends analyses of familiar and unfamiliar problems into courses of practical action with a high degree of effectiveness

*Note:* A student whose achievement is below 50% at the end of a course will not obtain a credit for the course.

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