2008

REVISED

The Ontario Curriculum
Grades 11 and 12

Science

reach every student

Ontario

CONTENTS

INTRODUCTION 3

Secondary Schools for the Twenty-first Century ... 3
The Place of Science in the Curriculum ... 3
The Goals of the Science Program ... 4
The Nature of Science ... 4
Roles and Responsibilities in the Science Program ... 7

THE PROGRAM IN SCIENCE 10

Overview of the Program ... 10
Curriculum Expectations ... 14
Strands in the Grade 11 and 12 Science Courses ... 17
Skills of Scientific Investigation (Inquiry and Research) ... 20

ASSESSMENT AND EVALUATION OF STUDENT ACHIEVEMENT 23

Basic Considerations ... 23
The Achievement Chart for Science ... 25
Evaluation and Reporting of Student Achievement ... 30
Reporting on Demonstrated Learning Skills ... 30

SOME CONSIDERATIONS FOR PROGRAM PLANNING 31

Instructional Approaches ... 31
Health and Safety in Science ... 32
Planning Science Programs for Students With Special Education Needs ... 33
Program Considerations for English Language Learners ... 36
Environmental Education ... 38
Antidiscrimination Education ... 39
Critical Thinking and Critical Literacy in Science ... 40
Literacy, Mathematical Literacy, and Investigation (Inquiry/Research) Skills ... 41
The Role of Information and Communications Technology in Science ... 42

Une publication équivalente est disponible en français sous le titre suivant : *Le curriculum de l'Ontario, 11e et 12e année – Sciences, 2008*.

This publication is available on the Ministry of Education's website, at www.edu.gov.on.ca.

The Ontario Skills Passport and Essential Skills 43
Career Education 43
Cooperative Education and Other Forms of Experiential Learning 43
Planning Program Pathways and Programs Leading to a Specialist High Skills Major 44

COURSES

BIOLOGY

Biology, Grade 11, University Preparation (SBI3U) 46
Biology, Grade 11, College Preparation (SBI3C) 60
Biology, Grade 12, University Preparation (SBI4U) 74

CHEMISTRY

Chemistry, Grade 11, University Preparation (SCH3U) 90
Chemistry, Grade 12, University Preparation (SCH4U) 104
Chemistry, Grade 12, College Preparation (SCH4C) 118

EARTH AND SPACE SCIENCE

Earth and Space Science, Grade 12, University Preparation (SES4U) 134

ENVIRONMENTAL SCIENCE

Environmental Science, Grade 11, University/College Preparation (SVN3M) 150
Environmental Science, Grade 11, Workplace Preparation (SVN3E) 164

PHYSICS

Physics, Grade 11, University Preparation (SPH3U) 180
Physics, Grade 12, University Preparation (SPH4U) 194
Physics, Grade 12, College Preparation (SPH4C) 208

SCIENCE

Science, Grade 12, University/College Preparation (SNC4M) 224
Science, Grade 12, Workplace Preparation (SNC4E) 238

GLOSSARY 253

INTRODUCTION

This document replaces *The Ontario Curriculum, Grades 11 and 12: Science, 2000*. Beginning in September 2009, all science programs for Grades 11 and 12 will be based on the expectations outlined in this document.

SECONDARY SCHOOLS FOR THE TWENTY-FIRST CENTURY

The goal of Ontario secondary schools is to support high-quality learning while giving individual students the opportunity to choose programs that suit their skills and interests. The updated Ontario curriculum, in combination with a broader range of learning options outside traditional classroom instruction, will enable students to better customize their high school education and improve their prospects for success in school and in life.

THE PLACE OF SCIENCE IN THE CURRICULUM

During the twentieth century, science played an increasingly important role in the lives of all Canadians. It underpins much of what we now take for granted, from life-saving pharmaceuticals to clean water, the places we live and work in, computers and other information technologies, and how we communicate with others. The impact of science on our lives will continue to grow as the twenty-first century unfolds. Consequently, scientific literacy for all has become a 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.

> *A scientifically and technologically literate person is one who can read and understand common media reports about science and technology, critically evaluate the information presented, and confidently engage in discussions and decision-making activities regarding issues that involve science and technology.*
>
> Science Co-ordinators' and Consultants' Association of Ontario (SCCAO)
> and Science Teachers' Association of Ontario (STAO/APSO),
> "Position Paper: The Nature of Science" (2006), p. 1

Achieving a high level of scientific literacy is not the same as becoming a scientist. The notion of thriving in a science-based world applies as much to a small-business person, a lawyer, a construction worker, a car mechanic, or a travel agent 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. 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; yet 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.

THE GOALS OF THE SCIENCE PROGRAM

Achievement of both excellence and equity underlies the three major goals of the secondary science program. *The Ontario Curriculum, Grades 11 and 12: Science, 2008* therefore outlines not only the skills and knowledge that students are expected to develop but also the attitudes that they will need to develop in order to use their knowledge and skills responsibly. The three goals of the science program are as follows:

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

Every course in the secondary science program focuses on these three goals. The goals are reflected within each strand of every course in the three overall expectations, which in turn are developed in corresponding sets of related specific expectations. The same three goals also underlie assessment of student achievement in science.

THE NATURE OF SCIENCE

> *The primary goal of science is to understand the natural and human-designed worlds. Science refers to certain processes used by humans for obtaining knowledge about nature, and to an organized body of knowledge about nature obtained by these processes. Science is a dynamic and creative activity with a long and interesting history. Many societies have contributed to the development of scientific knowledge and understanding. . . . Scientists continuously assess and judge the soundness of scientific knowledge claims by testing laws and theories, and modifying them in light of compelling new evidence or a re-conceptualization of existing evidence.*
>
> SCCAO and STAO/APSO, "Position Paper: The Nature of Science" (2006), pp. 1–2

Science is a way of knowing that seeks to describe and explain the natural and physical world. An important part of scientific literacy is an understanding of the nature of science, which includes an understanding of the following:

- what scientists, engineers, and technologists do as individuals and as a community
- how scientific knowledge is generated and validated, and what benefits, costs, and risks are involved in using this knowledge
- how science interacts with technology, society, and the environment

Occasionally, theories and concepts undergo change, but for the most part, the fundamental concepts of science – to do with phenomena such as the cellular basis of life, the laws of energy, the particle theory of matter – have proved stable.

Fundamental Concepts

> *Change the focus of the curriculum and instruction from teaching topics to "using" topics to teach and assess deeper, conceptual understanding.*
>
> Lynn Erickson, *Concept-Based Curriculum and Instruction* (2006), p. 7

Fundamental concepts are concepts about phenomena that have not changed fundamentally over time and that are common for all cultures. The fundamental concepts in science provide a framework for the deeper understanding of all scientific knowledge – a structure that facilitates integrated thinking as students draw from the knowledge base of science and see patterns and connections within the subdisciplines of science, and between science and other disciplines. The fundamental concepts addressed in the curricula for science and technology in Grades 1 to 8 and for science in Grades 9 to 12 are similar to concepts found in science curricula around the world.

As students progress through the curriculum from Grades 1 to 12, they extend and deepen their understanding of these fundamental concepts and learn to apply their understanding with increasing sophistication. The fundamental concepts are listed and described in the following chart.

FUNDAMENTAL CONCEPTS	
Matter	Matter is anything that has mass and occupies space. Matter has particular structural and behavioural characteristics.
Energy	Energy comes in many forms, and can change forms. It is required to make things happen (to do work). Work is done when a force causes movement.
Systems and Interactions	A system is a collection of living and/or non-living things and processes that interact to perform some function. A system includes inputs, outputs, and relationships among system components. Natural and human systems develop in response to, and are limited by, a variety of environmental factors.
Structure and Function	This concept focuses on the interrelationship between the function or use of a natural or human-made object and the form that the object takes.
Sustainability and Stewardship	Sustainability is the concept of meeting the needs of the present without compromising the ability of future generations to meet their needs. Stewardship involves understanding that we need to use and care for the natural environment in a responsible way and making the effort to pass on to future generations no less than what we have access to ourselves. Values that are central to responsible stewardship are: using non-renewable resources with care; reusing and recycling what we can; switching to renewable resources where possible.
Change and Continuity	Change is the process of becoming different over time, and can be quantified. Continuity represents consistency and connectedness within and among systems over time. Interactions within and among systems result in change and variations in consistency.

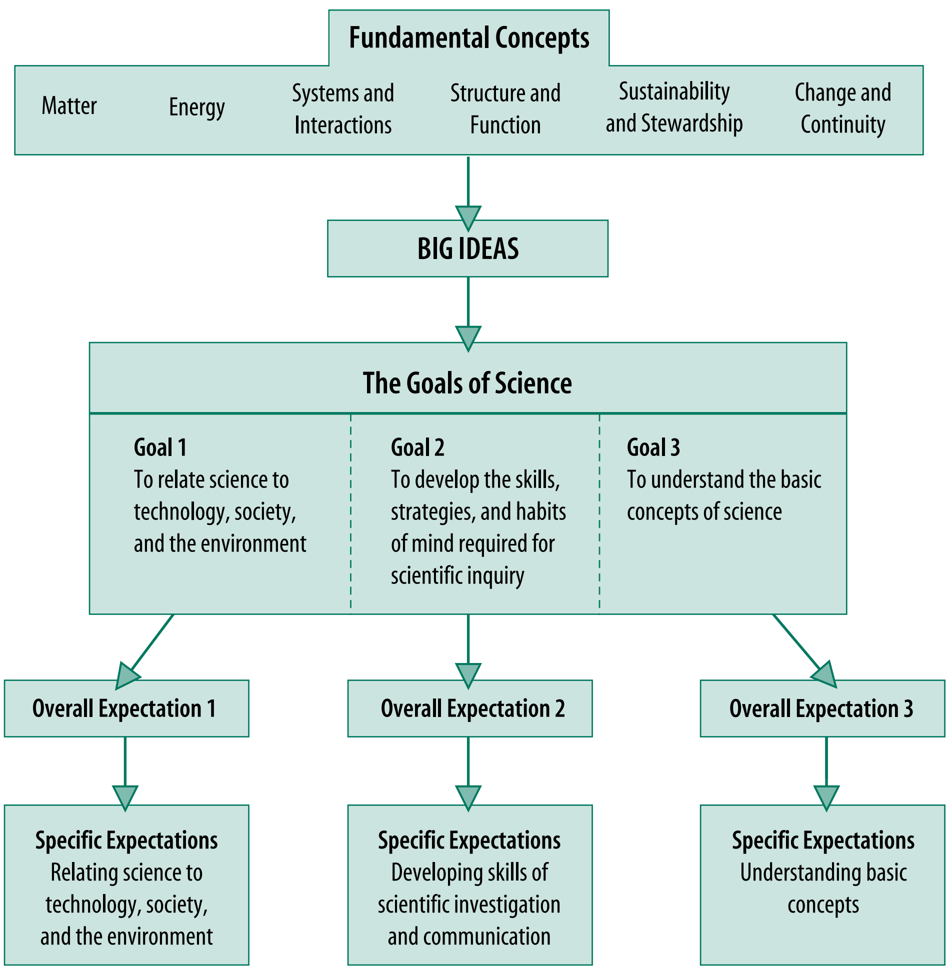
"Big Ideas"

> *Big ideas "go beyond discrete facts or skills to focus on larger concepts, principles, or processes."*
>
> Grant Wiggins and Jay McTighe, *Understanding by Design* (1998), p. 10

"Big ideas" are the broad, important understandings that students should retain long after they have forgotten many of the details of what they have studied in the classroom. They are the understandings that contribute to scientific literacy. The big ideas that students can take away from each course in this curriculum relate to some aspect of the fundamental concepts described in the preceding section. A list of the big ideas students need to understand appears at the start of every course in this document.

Developing a deeper understanding of the big ideas requires students to understand basic concepts, develop inquiry and problem-solving skills, and connect these concepts and skills to the world beyond the classroom. Teachers can help students gain such understanding by connecting learning based on the overall and specific expectations and the criteria in the achievement chart to the big ideas that relate to each course.

The relationship between the fundamental concepts, big ideas, the goals of the science program, and the overall and specific expectations is outlined in the chart that follows.



ROLES AND RESPONSIBILITIES IN THE SCIENCE PROGRAM

Students

Students have many responsibilities with regard to their learning, and these increase as they advance through secondary school. Students who are willing to make the effort required and who are able to monitor their thinking and learning strategies and apply themselves will soon discover that there is a direct relationship between this effort and their achievement, and will therefore be more motivated to work. Students who develop mental attitudes and ways of behaving that contribute to success in life will benefit as learners.

Successful mastery of scientific concepts and investigation skills requires students to have a sincere commitment to work and to the development of appropriate learning skills. Furthermore, students should actively pursue opportunities outside the classroom to extend and enrich their scientific understanding and skills. For example, students can make an effort to keep up with current events related to local, national, and international scientific discoveries and innovations.

Parents

Studies show that students perform better in school if their parents[1] are involved in their education. Parents who are familiar with the curriculum expectations know what is being taught in the courses their children are taking and what their children are expected to learn. This awareness enhances parents' ability to discuss school work with their children, to communicate with teachers, and to ask relevant questions about their children's progress. Knowledge of the expectations in the various courses also helps parents to interpret teachers' comments on student progress and to work with teachers to improve their children's learning.

Effective ways in which parents can support their children's learning include the following: attending parent-teacher interviews, participating in parent workshops and school council activities (including becoming a school council member), and encouraging their children to complete their assignments at home.

The science curriculum has the potential to stimulate interest in lifelong learning not only for students but also for their parents and all those with an interest in education. In addition to supporting regular school activities, parents may want to take an active interest in current events and issues in the field of science, and to provide their children with opportunities to question and reflect on the impact of these developments on their immediate lives, the environment, and society. Parents can also provide valuable support by encouraging children to take part in activities that develop responsible citizenship (such as participating in an environmental clean-up program in their neighbourhood) or that further their interest in science (such as volunteering at local science centres or children's museums).

Throughout the secondary science program, students will have opportunities to interact with living things and to work with a variety of equipment and materials. To help ensure students' safety, parents should inform teachers of any allergies that their children may have. Parents should also encourage their children to arrive at school prepared to participate safely in activities. Simple precautions such as wearing closed-toe shoes, tying back long hair, and removing loose jewellery (or taping it down in the case of Medic Alert bracelets) contribute to a safe environment when working within science classrooms.

1. In this document, *parent(s)* is used to refer to parents and guardians.

Teachers

Teachers are responsible for developing appropriate instructional strategies to help students achieve the curriculum expectations, as well as appropriate methods for assessing and evaluating student learning. Teachers bring enthusiasm and varied teaching and assessment approaches to the classroom, addressing individual students' needs and ensuring sound learning opportunities for every student.

Using a variety of instructional, assessment, and evaluation strategies, teachers provide numerous hands-on opportunities for students to develop and refine their investigation skills, including their problem-solving skills, critical and creative thinking skills, and communication skills, while discovering fundamental concepts through inquiry, exploration, observation, and research. The activities offered should enable students to relate and apply these concepts to the social, environmental, and economic conditions and concerns of the world in which they live. Opportunities to relate knowledge and skills to these wider contexts will motivate students to learn in a meaningful way and to become lifelong learners.

Teachers need to help students understand that problem solving of any kind often requires a considerable expenditure of time and energy and a good deal of perseverance. Teachers also need to encourage students to investigate, to reason, to explore alternative solutions, and to take the risks necessary to become successful problem solvers.

Science can play a key role in shaping students' views about life and learning. Science exists in a broader social and economic context. It is affected by the values and choices of individuals, businesses, and governments and, in turn, has a significant impact on society and the environment. Teachers must provide opportunities for students to develop habits of mind appropriate for meaningful work in science, including a commitment to accuracy, precision, and integrity in observation; respect for evidence; adherence to safety procedures; and respect for living things and the environment.

Teachers are also responsible for ensuring the safety of students during classroom activities and for encouraging and motivating students to assume responsibility for their own safety and the safety of others. They must also ensure that students acquire the knowledge and skills needed for safe participation in science activities.

Principals

The principal works in partnership with teachers and parents to ensure that each student has access to the best possible educational experience. The principal is also a community builder who creates an environment that is welcoming to all, and who ensures that all members of the school community are kept well informed.

To support student learning, principals ensure that the Ontario curriculum is being properly implemented in all classrooms through the use of a variety of instructional approaches and that appropriate resources are made available for teachers and students. To enhance teaching and student learning in all subjects, including science, principals promote learning teams and work with teachers to facilitate teacher participation in professional development activities. Principals are responsible for ensuring that every student who has an Individual Education Plan (IEP) is receiving the modifications and/or accommodations described in his or her plan – in other words, that the IEP is properly developed, implemented, and monitored.

Community Partners

Community partners in areas related to science can be an important resource for schools and students. They can provide support for students in the classroom and can be models of how the knowledge and skills acquired through the study of the curriculum relate to life beyond school. As mentors, they can enrich not only the educational experience of students but also the life of the community. For example, schools can make use of community groups that recruit practising scientists (e.g., engineers, optometrists, veterinarians, geologists, lab technicians) to provide in-class workshops for students that are based on topics, concepts, and skills from the curriculum.

Schools and school boards can play a role by coordinating efforts with community partners. They can involve community volunteers in supporting science instruction and in promoting a focus on scientific literacy in and outside the school. Community partners can be included in events held in the school (such as parent education nights and science fairs), and school boards can collaborate with leaders of existing community science programs for students, including programs offered in community centres, libraries, and local museums and science centres.

THE PROGRAM IN SCIENCE

OVERVIEW OF THE PROGRAM

The overall aim of the secondary science program is to ensure scientific literacy for every secondary school graduate. To better achieve this aim, all courses in the program are designed to focus on science not only as an intellectual pursuit but also as an activity-based enterprise within a social context.

The senior science courses build on the Grade 9 and 10 science program, incorporating the same goals of science and fundamental concepts on which that program was based. Both programs are founded on the premise that students learn science most effectively when they are active participants in their own learning. Such participation is achieved when science concepts and procedures are introduced through an investigative approach and are connected to students' prior knowledge in meaningful ways. The Grade 11 and 12 science curriculum is designed to help students prepare for university, college, or the workplace by building a solid conceptual and procedural foundation in science that enables them to apply their knowledge and skills in a variety of ways and successfully further their learning.

An important component of every course in the science program is the development of students' ability to relate science to technology, society, and the environment. Students are encouraged to apply their understanding of science to real-world situations in these areas and to develop knowledge, skills, and attitudes that they will take with them beyond the science classroom.

The Grade 11 and 12 science program is designed to help students become scientifically literate. One aspect of scientific literacy is the ability to recognize, interpret, and produce representations of scientific information in forms ranging from written and oral reports, drawings and diagrams, and graphs and tables of values to equations, physical models, and computer simulations. As students' scientific knowledge and skills develop through the grades, they will become conversant with increasingly sophisticated forms and representations of scientific information.

The senior science curriculum also builds on students' experience with a variety of the sophisticated yet easy-to-use computer applications and simulations that are so prevalent in today's world. The curriculum integrates these technologies into the learning and doing of science in ways that help students develop investigation skills, extend their understanding of scientific concepts, enable them to solve meaningful problems, and familiarize them with technologies that can be applied in various other areas of endeavour. In this curriculum, technology does not replace skills acquisition; rather, it is treated as a learning tool that helps students explore concepts and hone skills.

A balanced science program must include varied opportunities for students to practise and enhance their scientific investigations skills. Like the Grade 9 and 10 science courses, the senior secondary curriculum focuses on refining specific skills that best enable students to develop their understanding of scientific concepts and acquire related knowledge.

Courses in Grades 11 and 12

Four types of courses are offered in the Grade 11 and 12 science program: university preparation, university/college preparation, college preparation, and workplace preparation courses. Students choose between course types on the basis of their interests, achievement, and postsecondary goals.

The course types offered in Grades 11 and 12 are defined as follows:

University preparation courses are designed to equip students with the knowledge and skills they need to meet the entrance requirements for university programs.

University/college preparation courses are designed to equip students with the knowledge and skills they need to meet the entrance requirements for specific programs offered at universities and colleges.

College preparation courses are designed to equip students with the knowledge and skills they need to meet the requirements for entrance to most college programs or for admission to specific apprenticeship or other training programs.

Workplace preparation courses are designed to equip students with the knowledge and skills they need to meet the expectations of employers, if they plan to enter the workplace directly after graduation, or the requirements for admission to many apprenticeship or other training programs.

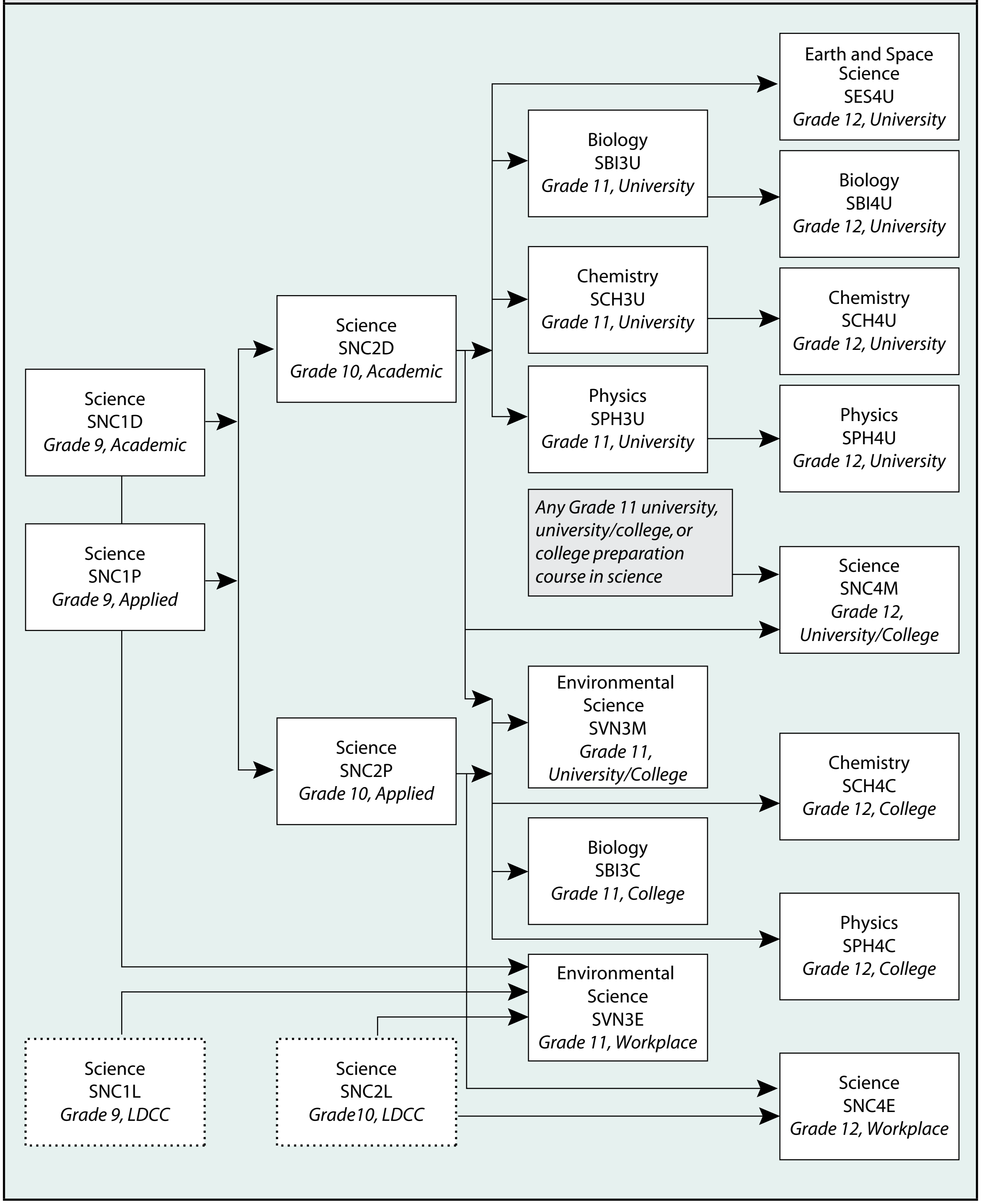
A table showing all Grade 11 and 12 science courses is given on page 12, and the prerequisite chart for all Grade 9–12 science courses appears on page 13.

Courses in Science, Grades 11 and 12				
Grade	**Course Name**	**Course Type**	**Course Code**	**Prerequisite**
Biology				
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
Chemistry				
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
Earth and Space Science				
12	Earth and Space Science	University	SES4U	Grade 10 Science, Academic
Environmental Science				
11	Environmental Science	University/ College	SVN3M	Grade 10 Science, Academic or Applied
11	Environmental Science	Workplace	SVN3E	Grade 9 Science, Academic or Applied, or a Grade 9 or Grade 10 LDCC*
Physics				
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
Science				
12	Science	University/ College	SNC4M	Grade 10 Science, Academic, or any Grade 11 university, university/college, or college preparation course in the science curriculum
12	Science	Workplace	SNC4E	Grade 10 Science, Applied, or a Grade 10 LDCC*

Note: Each of the courses listed above is worth one credit.
*LDCC – locally developed compulsory credit course

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 prerequisites for them. It does not attempt to depict all possible movements from course to course.



Note: Dotted lines represent locally developed compulsory credit courses (LDCCs), which are not outlined in this curriculum document.

Half-Credit Courses

The courses outlined in the Grade 9 and 10 and Grade 11 and 12 science curriculum documents are designed as full-credit courses. However, *with the exception of the Grade 12 university preparation and university/college preparation courses*, they may also be delivered as half-credit courses.

Half-credit courses, which require a minimum of fifty-five hours of scheduled instructional time, 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. The expectations for each half-credit course must be drawn from all strands of the full course and must be 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 they may 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 October Report.

CURRICULUM EXPECTATIONS

The Ontario Curriculum, Grades 11 and 12: Science, 2008 identifies the curriculum expectations for each course. The expectations describe the knowledge and skills that students are expected to develop and demonstrate in their class work and investigations, on tests, and in various other activities on which their achievement is assessed and evaluated.

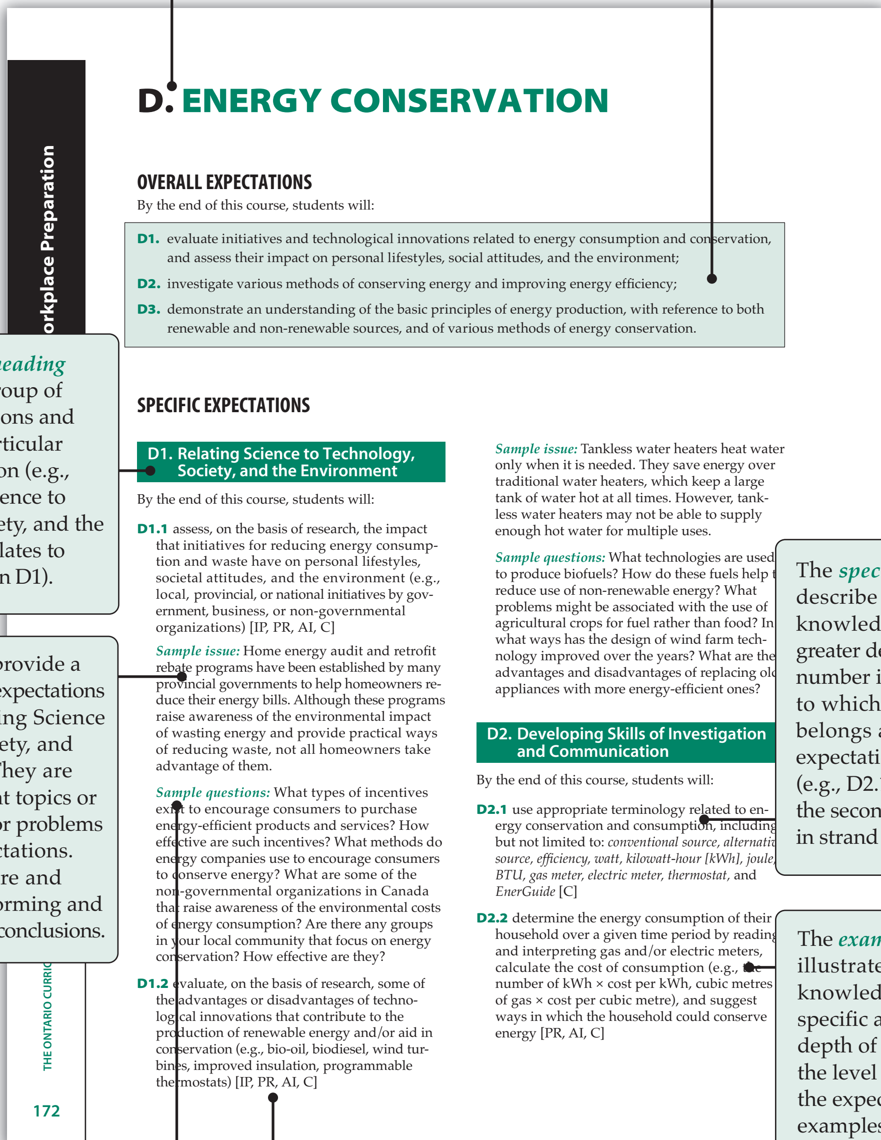
Two sets of expectations – overall expectations and specific expectations – are listed for each *strand*, or broad area of the curriculum. (The strands are numbered A, B, C, D, E, and F.) Taken together, the overall expectations and specific expectations represent the mandated curriculum.

The *overall expectations* describe in general terms the knowledge and skills that students are expected to demonstrate by the end of each course. There are three overall expectations for each content strand in each course in science.

The *specific expectations* describe the expected knowledge and skills in greater detail. The specific expectations are grouped under numbered subheadings, each of which indicates the strand and the overall expectation to which the group of specific expectations corresponds (e.g., "B2" indicates that the group relates to overall expectation 2 in strand B). The organization of expectations into groups 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 develop and present various lessons and learning activities for their students.

Each of the Grade 11 and 12 science courses is organized into six ***strands***, numbered A, B, C, D, E, and F.

The ***overall expectations*** describe in general terms the knowledge and skills students are expected to demonstrate by the end of each course. Two or three overall expectations are provided for each strand in every course. The numbering of overall expectations indicates the strand to which they belong (e.g., D1 through D3 are the overall expectations for strand D).



orkplace Preparation

D. ENERGY CONSERVATION

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. evaluate initiatives and technological innovations related to energy consumption and conservation, and assess their impact on personal lifestyles, social attitudes, and the environment;

D2. investigate various methods of conserving energy and improving energy efficiency;

D3. demonstrate an understanding of the basic principles of energy production, with reference to both renewable and non-renewable sources, and of various methods of energy conservation.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 assess, on the basis of research, the impact that initiatives for reducing energy consumption and waste have on personal lifestyles, societal attitudes, and the environment (e.g., local, provincial, or national initiatives by government, business, or non-governmental organizations) [IP, PR, AI, C]

Sample issue: Home energy audit and retrofit rebate programs have been established by many provincial governments to help homeowners reduce their energy bills. Although these programs raise awareness of the environmental impact of wasting energy and provide practical ways of reducing waste, not all homeowners take advantage of them.

Sample questions: What types of incentives exist to encourage consumers to purchase energy-efficient products and services? How effective are such incentives? What methods do energy companies use to encourage consumers to conserve energy? What are some of the non-governmental organizations in Canada that raise awareness of the environmental costs of energy consumption? Are there any groups in your local community that focus on energy conservation? How effective are they?

D1.2 evaluate, on the basis of research, some of the advantages or disadvantages of technological innovations that contribute to the production of renewable energy and/or aid in conservation (e.g., bio-oil, biodiesel, wind turbines, improved insulation, programmable thermostats) [IP, PR, AI, C]

Sample issue: Tankless water heaters heat water only when it is needed. They save energy over traditional water heaters, which keep a large tank of water hot at all times. However, tankless water heaters may not be able to supply enough hot water for multiple uses.

Sample questions: What technologies are used to produce biofuels? How do these fuels help t reduce use of non-renewable energy? What problems might be associated with the use of agricultural crops for fuel rather than food? In what ways has the design of wind farm technology improved over the years? What are the advantages and disadvantages of replacing old appliances with more energy-efficient ones?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to energy conservation and consumption, including but not limited to: *conventional source, alternati source, efficiency, watt, kilowatt-hour [kWh], joule, BTU, gas meter, electric meter, thermostat*, and *EnerGuide* [C]

D2.2 determine the energy consumption of their household over a given time period by reading and interpreting gas and/or electric meters, calculate the cost of consumption (e.g., the number of kWh × cost per kWh, cubic metres of gas × cost per cubic metre), and suggest ways in which the household could conserve energy [PR, AI, C]

THE ONTARIO CURRIC

172

A ***numbered subheading*** identifies each group of specific expectations and relates to one particular overall expectation (e.g., "D1. Relating Science to Technology, Society, and the Environment" relates to overall expectation D1).

The ***sample issues*** provide a broader context for expectations in the strand Relating Science to Technology, Society, and the Environment. They are examples of relevant topics or open-ended issues or problems related to the expectations. Students can explore and debate the issues, forming and justifying their own conclusions.

The ***specific expectations*** describe the expected knowledge and skills in greater detail. The expectation number identifies the strand to which the expectation belongs and the overall expectation to which it relates (e.g., D2.1 and D2.2 relate to the second overall expectation in strand D).

The ***examples*** are meant to illustrate the kind of knowledge or skills, the specific area of learning, the depth of learning, and/or the level of complexity that the expectation entails. The examples are illustrations only, not requirements. They appear in parentheses within specific expectations.

The ***sample questions*** are intended to help teachers initiate open discussions on a range of current issues related to the topic of the expectation. They can also provide students with a focus for inquiry and/or research.

The ***abbreviations in square brackets*** following many specific expectations link the expectation to one or more of the *four broad areas of scientific investigation skills* (see p. 20). In achieving the expectation, students are expected to apply skills from the area(s) specified by the abbreviation(s).

Many of the specific expectations are accompanied by examples, given in parentheses, as well as “sample issues” and “sample questions”. The examples, sample issues, and sample questions are meant to illustrate the kind of knowledge or skill, the specific area of learning, the depth of learning, and/or the level of complexity that the expectation entails. They have been developed to model appropriate practice for the grade and are meant to serve as a guide for teachers rather than an exhaustive or mandatory list. Teachers can choose to use the examples and sample issues and questions that are appropriate for their classrooms, or they may develop their own approaches that reflect a similar level of complexity. Whatever the specific ways in which the requirements outlined in the expectations are implemented in the classroom, they must, wherever possible, be inclusive and reflect the diversity of the student population and the population of the province.

The Expectations and the Goals of the Science Program

The three overall expectations in the content strands of every course, and their corresponding groups of specific expectations, are closely connected with the three goals of the science program (see page 4). The relationship between the goals and the expectations is briefly described below:

Goal 1. ***To relate science to technology, society, and the environment***

The first overall expectation in each content strand focuses on relating science to technology, society, and the environment (STSE). These expectations and their related clusters of specific expectations are positioned at the beginning of the strands to better align the curriculum with the optimal approach to teaching and learning science, and to emphasize the importance of scientific, technological, and environmental literacy for all students. The STSE expectations provide the context for developing the related skills and conceptual knowledge necessary for making connections between scientific, technological, social, and environmental issues. The STSE expectations often focus on aspects of environmental education.

Goal 2. ***To develop the skills, strategies, and habits of mind required for scientific investigation***

The skills needed for developing scientific literacy are described in the second overall expectation in each strand and elaborated in its corresponding group of specific expectations, found under the heading “Developing Skills of Investigation and Communication”.

Goal 3. ***To understand the basic concepts of science***

The conceptual knowledge that students are expected to acquire in the strand is described in the third overall expectation and elaborated in its corresponding group of specific expectations, found under the heading “Understanding Basic Concepts”.

The incorporation of the three goals and their interrelationships in the curriculum expectations reinforces the idea that learning in science cannot be viewed as merely the learning of facts. Rather, it involves students’ making connections and acquiring, in age-appropriate ways, the knowledge and skills that will help them to understand and consider critically the role of science in their daily lives, and the impact of scientific developments on society and the environment.

STRANDS IN THE GRADE 11 AND 12 SCIENCE COURSES

The expectations for the Grade 11 and 12 science courses are organized in six distinct but related strands. The first strand (strand A) focuses on scientific investigation skills, which are similar for all courses; the remaining five strands (strands B through F) represent the major content areas for each course.

Strand A: Scientific Investigation Skills

The first strand outlines required learning related to scientific investigation skills (SIS). The expectations in this strand describe the skills that are considered to be essential for all types of scientific investigation (see page 20). These skills apply to all areas of course content and must be developed in conjunction with learning in all five content strands of the course. (Scientific investigation skills were also a focus of the elementary science and technology curriculum, but they were embedded in expectations within the content strands.)

The scientific investigation skills are organized under subheadings related to the four broad areas of investigation – initiating and planning; performing and recording; analysing and interpreting; and communicating. To highlight the connection between skills in these broad areas of investigation and the expectations in the other five strands of a course, abbreviations in square brackets are given after each specific expectation in the first two groups of specifics in every strand (under the headings "Relating Science to Technology, Society, and the Environment" and "Developing Skills of Investigation and Communication"). These abbreviations link a specific expectation to the applicable area(s) of investigation skills. For example, "[IP]" indicates that, with achievement of the specific expectation, a student will have developed skills relating to initiating and planning. Teachers should ensure that students develop the scientific investigation skills in appropriate ways as they work to achieve the curriculum expectations in the content strands. Students' mastery of these skills must be assessed and evaluated as part of students' achievement of the overall expectations for the course.

Strands B through F: Content Areas

Stands B through F in the Grade 11 and 12 courses focus on major topics in the scientific discipline under study. The content for each course includes, where possible, topics set out in the pan-Canadian *Commom Framework of Science Learning Outcomes* (CMEC, 1997). The strands for all of the Grade 11 and 12 courses, as well as the topics in the strands of the Grade 9 and 10 courses, are outlined in the chart on pages 18–19.

Grades 9 and 10 – Strands and Topics

Course	***Strand B: Biology***	***Strand C: Chemistry***	***Strand D: Earth and Space Science***	***Strand E: Physics***
Gr. 9, Academic (SNC1D)	Sustainable Ecosystems	Atoms, Elements, and Compounds	The Study of the Universe	The Characteristics of Electricity
Gr. 9, Applied (SNC1P)	Sustainable Ecosystems and Human Activity	Exploring Matter	Space Exploration	Electrical Applications
Gr. 10, Academic (SNC2D)	Tissues, Organs, and Systems of Living Things	Chemical Reactions	Climate Change	Light and Geometric Optics
Gr. 10, Applied (SNC2P)	Tissues, Organs, and Systems	Chemical Reactions and Their Practical Application	Earth's Dynamic Climate	Light and Applications of Optics

Grades 11 and 12 – Strands

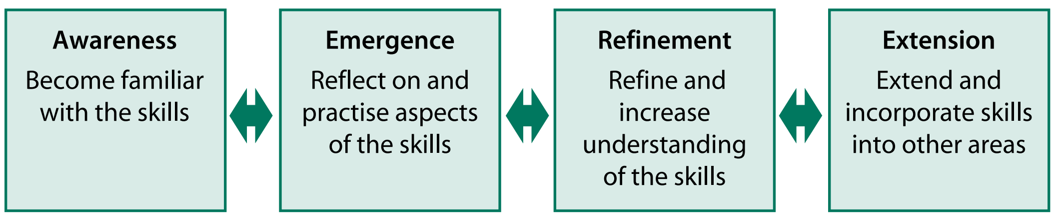
Course	***Strand B***	***Strand C***	***Strand D***	***Strand E***	***Strand F***
Biology, Gr. 11, University (SBI3U)	Diversity of Living Things	Evolution	Genetic Processes	Animals: Structure and Function	Plants: Anatomy, Growth, and Function
Biology, Gr. 11, College (SBI3C)	Cellular Biology	Microbiology	Genetics	Anatomy of Mammals	Plants in the Natural Environment
Biology, Gr. 12, University (SBI4U)	Biochemistry	Metabolic Processes	Molecular Genetics	Homeostasis	Population Dynamics
Chemistry, Gr. 11, University (SCH3U)	Matter, Chemical Trends, and Chemical Bonding	Chemical Reactions	Quantities in Chemical Reactions	Solutions and Solubility	Gases and Atmospheric Chemistry
Chemistry, Gr. 12, University (SCH4U)	Organic Chemistry	Structure and Properties of Matter	Energy Changes and Rates of Reaction	Chemical Systems and Equilibrium	Electrochemistry
Chemistry, Gr. 12, College (SCH4C)	Matter and Qualitative Analysis	Organic Chemistry	Electrochemistry	Chemical Calculations	Chemistry in the Environment

Grades 11 and 12 – Strands (*continued*)					
Course	***Strand B***	***Strand C***	***Strand D***	***Strand E***	***Strand F***
Earth and Space Science, Gr. 12, University (SES4U)	Astronomy (Science of the Universe)	Planetary Science (Science of the Solar System)	Recording Earth's Geological History	Earth Materials	Geological Processes
Environmental Science, Gr. 11, University/College (SVN3M)	Scientific Solutions to Contemporary Environmental Challenges	Human Health and the Environment	Sustainable Agriculture and Forestry	Reducing and Managing Waste	Conservation of Energy
Environmental Science, Gr. 11, Workplace (SVN3E)	Human Impact on the Environment	Human Health and the Environment	Energy Conservation	Natural Resource Science and Management	The Safe and Environmentally Responsible Workplace
Physics, Gr. 11, University (SPH3U)	Kinematics	Forces	Energy and Society	Waves and Sound	Electricity and Magnetism
Physics, Gr. 12, University (SPH4U)	Dynamics	Energy and Momentum	Gravitational, Electric, and Magnetic Fields	The Wave Nature of Light	Revolutions in Modern Physics: Quantum Mechanics and Special Relativity
Physics, Gr. 12, College (SPH4C)	Motion and Its Applications	Mechanical Systems	Electricity and Magnetism	Energy Transformations	Hydraulic and Pneumatic Systems
Science, Gr. 12, University/College (SNC4M)	Medical Technologies	Pathogens and Diseases	Nutritional Science	Science and Public Health Issues	Biotechnology
Science, Gr. 12, Workplace (SNC4E)	Hazards in the Workplace	Chemicals in Consumer Products	Disease and Its Prevention	Electricity at Home and Work	Nutritional Science

SKILLS OF SCIENTIFIC INVESTIGATION (INQUIRY AND RESEARCH)

The goal of science education is more than just providing students with a knowledge of facts. Mastery of the subject can no longer be evaluated solely in terms of students' ability to recall specialized terminology, memorize isolated facts, or repeat a theory. Rather, students must be given opportunities to learn through investigation. In doing so, they can practise and become proficient in various scientific investigation skills. These skills not only develop critical thinking and allow students to extend their understanding of science; they are also useful in students' everyday lives and will help them in pursuing their post-secondary goals, whether in science or some other area of endeavour.

As students advance from grade to grade, they practise these skills more fully and independently and in increasingly demanding contexts. Initially, students become aware of and familiar with each new skill. With emerging understanding, students reflect on and practise aspects of these skills when conducting investigations. As their knowledge and confidence grow, students begin to implement the skill more fully. Through repeated use, they are able to increase and refine their understanding of and proficiency in each skill. Finally, once they become proficient, they can extend skills, incorporating them into other areas of study as well as everyday activities.



Four Broad Areas of Scientific Investigation

Students learn to apply scientific investigation skills in four broad areas: *initiating and planning; performing and recording; analysing and interpreting*; and *communicating*.

- *Initiating and planning* skills include formulating questions or hypotheses or making predictions about ideas, issues, problems, or the relationships between observable variables, and planning investigations to answer those questions or test those hypotheses.
- *Performing and recording* skills include conducting research by gathering, organizing, and recording information, and safely conducting inquiries to make observations and to collect, organize, and record data.
- *Analysing and interpreting* skills include evaluating the adequacy of the data from inquiries or the information from research sources, and analysing the data or information in order to draw and justify conclusions.
- *Communication* skills include using appropriate linguistic, numeric, symbolic, and graphic modes of representation, and a variety of forms, to communicate ideas, procedures, and results.

Skills in these four areas are not necessarily performed sequentially. As the figure on page 21 illustrates, investigation may begin in any one of the areas, and students will tend to move back and forth among the areas as they practise and refine their skills. Students should

Interactions Among the Four Broad Areas of Skills

Initiating and Planning

Formulate questions or hypotheses or make predictions about issues, problems, or the relationships between observable variables, and plan investigations to answer the questions or test the hypotheses/predictions

- Think and brainstorm
- Identify problems/issues to explore
- Formulate questions
- Identify variables
- Make predictions, develop hypotheses
- Define and clarify the inquiry or research problem
- Identify and locate research sources
- Select instruments and materials
- Plan for safe practices in investigations

Communicating

Use appropriate linguistic, numeric, symbolic, and graphic modes to communicate ideas, procedures, results, and conclusions in a variety of ways

- Communicate ideas, procedures, and results in a variety of forms (e.g., orally, in writing, using electronic presentations)
- Use appropriate formats to communicate results (e.g., reports, data tables, scientific models)
- Use numeric, symbolic, and graphic modes of representation
- Express results accurately and precisely
- Use correct terminology and appropriate units of measurement

Performing and Recording

Conduct research by gathering, organizing, and recording information from appropriate sources; and conduct inquiries, making observations and collecting, organizing, and recording qualitative and quantitative data

- Conduct inquiries safely
- Observe, and record observations
- Use equipment, materials, and technology accurately and safely
- Control variables, as appropriate
- Adapt or extend procedures
- Gather, organize, and record relevant information from research, and data from inquiries
- Acknowledge sources, using an accepted form of documentation

Analysing and Interpreting

Evaluate the reliability of data from inquiries, and of information from research sources, and analyse the data or information to identify patterns and relationships and draw and justify conclusions

- Think critically and logically
- Evaluate reliability of data and information
- Process and synthesize data
- Evaluate whether data supports or refutes hypotheses/predictions
- Interpret data/information to identify patterns and relationships
- Solve problems
- Draw conclusions
- Justify conclusions
- Identify sources of error or bias

reflect on their questions, procedures, and findings, and should be prepared to modify them as they proceed through an investigation. In addition, each investigation is unique and will require a particular mix and sequence of skills.

Individual students may develop specific skills earlier or later than their peers, and some students may need to revisit particular skills at different points within the science curriculum. Skills in different areas may be practised and refined in the context of tasks and activities that are not necessarily part of a single, complete investigation that involves all four areas.

> *The purpose of inquiry and research is to encourage high levels of critical thinking so that processes and resources are appropriate, conclusions are based on supporting evidence, and problems are solved and decisions made that will extend learning for a lifetime.*
>
> Ontario School Library Association, *Information Studies: Kindergarten to Grade 12* (1999), p. 16

ASSESSMENT AND EVALUATION OF STUDENT ACHIEVEMENT

BASIC CONSIDERATIONS

The primary purpose of assessment and evaluation is to improve student learning. Information gathered through assessment helps teachers to determine students' strengths and weaknesses in their achievement of the curriculum expectations in each course. This information also serves to guide teachers in adapting curriculum and instructional approaches to students' needs and in assessing the overall effectiveness of programs and classroom practices.

Assessment is the process of gathering information from a variety of sources (including assignments, day-to-day observations, conversations or conferences, demonstrations, projects, performances, and tests) that accurately reflects how well a student is achieving the curriculum expectations in a course. As part of assessment, teachers provide students with descriptive feedback that guides their efforts towards improvement. Evaluation refers to the process of judging the quality of student work on the basis of established criteria, and assigning a value to represent that quality.

Assessment and evaluation will be based on the provincial curriculum expectations and the achievement levels outlined in this document.

In order to ensure that assessment and evaluation are valid and reliable, and that they lead to the improvement of student learning, teachers must use assessment and evaluation strategies that:

- address both what students learn and how well they learn;
- are based both on the categories of knowledge and skills and on the achievement level descriptions given in the achievement chart on pages 28–29;
- are varied in nature, administered over a period of time, and designed to provide opportunities for students to demonstrate the full range of their learning;
- are appropriate for the learning activities used, the purposes of instruction, and the needs and experiences of the students;

- are fair to all students;
- accommodate students with special education needs, consistent with the strategies outlined in their Individual Education Plan;
- accommodate the needs of students who are learning the language of instruction;
- ensure that each student is given clear directions for improvement;
- promote students' ability to assess their own learning and to set specific goals;
- include the use of samples of students' work that provide evidence of their achievement;
- are communicated clearly to students and parents at the beginning of the school year and at other appropriate points throughout the school year.

Evaluation of Achievement of Overall Expectations

All curriculum expectations must be accounted for in instruction, but evaluation focuses on students' achievement of the overall expectations. A student's achievement of the overall expectations is evaluated on the basis of his or her achievement of related specific expectations. The overall expectations are broad in nature, and the specific expectations define the particular content or scope of the knowledge and skills referred to in the overall expectations. Teachers will use their professional judgement to determine which specific expectations should be used to evaluate achievement of the overall expectations, and which ones will be covered in instruction and assessment (e.g., through direct observation) but not necessarily evaluated.

Levels of Achievement

The characteristics given in the achievement chart (pages 28–29) for level 3 represent the "provincial standard" for achievement of the expectations. A complete picture of achievement at level 3 in a science course can be constructed by reading from top to bottom in the shaded column of the achievement chart, headed "70–79% (Level 3)". Parents of students achieving at level 3 can be confident that their children will be prepared for work in subsequent courses.

Level 1 identifies achievement that falls much below the provincial standard, while still reflecting a passing grade. Level 2 identifies achievement that approaches the standard. Level 4 identifies achievement that surpasses the standard. It should be noted that achievement at level 4 does not mean that the student has achieved expectations beyond those specified for a particular course. It indicates that the student has achieved all or almost all of the expectations for that course, and that he or she demonstrates the ability to use the knowledge and skills specified for that course in more sophisticated ways than a student achieving at level 3.

THE ACHIEVEMENT CHART FOR SCIENCE

The achievement chart that follows identifies four categories of knowledge and skills in science. The achievement chart is a standard province-wide guide to be used by teachers. It enables teachers to make judgements about student work that are based on clear performance standards and on a body of evidence collected over time.

The purpose of the achievement chart is to:

- provide a common framework that encompasses all curriculum expectations for all courses outlined in this document;
- guide the development of high-quality assessment tasks and tools (including rubrics);
- help teachers to plan instruction for learning;
- assist teachers in providing meaningful feedback to students;
- provide various categories and criteria with which to assess and evaluate students' learning.

Categories of Knowledge and Skills

The categories, defined by clear criteria, represent four broad areas of knowledge and skills within which the subject expectations for any given course are organized. The four categories should be considered as interrelated, reflecting the wholeness and interconnectedness of learning.

The categories of knowledge and skills are described as follows:

Knowledge and Understanding. Subject-specific content acquired in each course (knowledge), and the comprehension of its meaning and significance (understanding).

Thinking and Investigation. The use of critical and creative thinking skills and inquiry, research, and problem-solving skills and/or processes.

Communication. The conveying of meaning through various forms.

Application. The use of knowledge and skills to make connections within and between various contexts.

Teachers will ensure that student work is assessed and/or evaluated in a balanced manner with respect to the four categories, and that achievement of particular expectations is considered within the appropriate categories.

Criteria

Within each category in the achievement chart, criteria are provided that are subsets of the knowledge and skills that define each category. The criteria for each category are listed below:

Knowledge and Understanding

- knowledge of content (e.g., facts, terminology, definitions, safe use of equipment and materials)
- understanding of content (e.g., concepts, ideas, theories, principles, procedures, processes)

Thinking and Investigation

- use of initiating and planning skills and strategies (e.g., formulating questions, identifying the problem, developing hypotheses, selecting strategies and resources, developing plans)
- use of processing skills and strategies (e.g., performing and recording, gathering evidence and data, observing, manipulating materials and using equipment safely, solving equations, proving)
- use of critical/creative thinking processes, skills, and strategies (e.g., analysing, interpreting, problem solving, evaluating, forming and justifying conclusions on the basis of evidence)

Communication

- expression and organization of ideas and information (e.g., clear expression, logical organization) in oral, visual, and/or written forms (e.g., diagrams, models)
- communication for different audiences (e.g., peers, adults) and purposes (e.g., to inform, to persuade) in oral, visual, and/or written forms
- use of conventions, vocabulary, and terminology of the discipline in oral, visual, and written forms (e.g., symbols, formulae, scientific notation, SI units)

Application

- application of knowledge and skills (e.g., concepts and processes, safe use of equipment, scientific investigation skills) in familiar contexts
- transfer of knowledge and skills (e.g., concepts and processes, safe use of equipment, scientific investigation skills) to unfamiliar contexts
- making connections between science, technology, society, and the environment (e.g., assessing the impact of science on technology, people and other living things, and the environment)
- proposing courses of practical action to deal with problems relating to science, technology, society, and the environment

Descriptors

A "descriptor" indicates the characteristic of the student's performance, with respect to a particular criterion, on which assessment or evaluation is focused. In the achievement chart, *effectiveness* is the descriptor used for each criterion in the Thinking and Investigation, Communication, and Application categories. What constitutes effectiveness in any given performance task will vary with the particular criterion being considered. Assessment of effectiveness may therefore focus on a quality such as appropriateness, clarity, accuracy, precision, logic, relevance, significance, fluency, flexibility, depth, or breadth, as appropriate for the particular criterion. For example, in the Thinking and Investigation category, assessment of effectiveness might focus on the degree of relevance or depth apparent in an analysis; in the Communication category, on clarity of expression or logical organization of information and ideas; or in the Application category, on appropriateness or breadth in the making of connections. Similarly, in the Knowledge and Understanding category, assessment of knowledge might focus on accuracy, and assessment of understanding might focus on the depth of an explanation. Descriptors help teachers to focus their assessment and evaluation on specific knowledge and skills for each category and criterion, and help students to better understand exactly what is being assessed and evaluated.

Qualifiers

A specific "qualifier" is used to define each of the four levels of achievement – that is, *limited* for level 1, *some* for level 2, *considerable* for level 3, and *a high degree* or *thorough* for level 4. A qualifier is used along with a descriptor to produce a description of performance at a particular level. For example, the description of a student's performance at level 3 with respect to the first criterion in the Thinking and Investigation category would be: "The student uses initiating and planning skills and strategies with considerable effectiveness".

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 provided with numerous and varied opportunities to demonstrate the full extent of their achievement of the curriculum expectations across all four categories of knowledge and skills.

ACHIEVEMENT CHART: SCIENCE, GRADES 9–12

Categories	50–59% (Level 1)	60–69% (Level 2)	70–79% (Level 3)	80–100% (Level 4)
Knowledge and Understanding – Subject-specific content acquired in each course (knowledge), and the comprehension of its meaning and significance (understanding)				
	The student:			
Knowledge of content *(e.g., facts, terminology, definitions, safe use of equipment and materials)*	demonstrates limited knowledge of content	demonstrates some knowledge of content	demonstrates considerable knowledge of content	demonstrates thorough knowledge of content
Understanding of content *(e.g., concepts, ideas, theories, principles, procedures, processes)*	demonstrates limited understanding of content	demonstrates some understanding of content	demonstrates considerable understanding of content	demonstrates thorough understanding of content
Thinking and Investigation – The use of critical and creative thinking skills and inquiry, research, and problem-solving skills and/or processes				
	The student:			
Use of initiating and planning skills and strategies *(e.g., formulating questions, identifying the problem, developing hypotheses, selecting strategies and resources, developing plans)*	uses initiating and planning skills and strategies with limited effectiveness	uses initiating and planning skills and strategies with some effectiveness	uses initiating and planning skills and strategies with considerable effectiveness	uses initiating and planning skills and strategies with a high degree of effectiveness
Use of processing skills and strategies *(e.g., performing and recording, gathering evidence and data, observing, manipulating materials and using equipment safely, solving equations, proving)*	uses processing skills and strategies with limited effectiveness	uses processing skills and strategies with some effectiveness	uses processing skills and strategies with considerable effectiveness	uses processing skills and strategies with a high degree of effectiveness
Use of critical/creative thinking processes, skills, and strategies *(e.g., analysing, interpreting, problem solving, evaluating, forming and justifying conclusions on the basis of evidence)*	uses critical/ creative thinking processes, skills, and strategies with limited effectiveness	uses critical/ creative thinking processes, skills, and strategies with some effectiveness	uses critical/ creative thinking processes, skills, and strategies with considerable effectiveness	uses critical/ creative thinking processes, skills, and strategies with a high degree of effectiveness
Communication – The conveying of meaning through various forms				
	The student:			
Expression and organization of ideas and information *(e.g., clear expression, logical organization)* **in oral, visual, and/or written forms** *(e.g., diagrams, models)*	expresses and organizes ideas and information with limited effectiveness	expresses and organizes ideas and information with some effectiveness	expresses and organizes ideas and information with considerable effectiveness	expresses and organizes ideas and information with a high degree of effectiveness

Categories	50–59% (Level 1)	60–69% (Level 2)	70–79% (Level 3)	80–100% (Level 4)
Communication (*continued*)				
	The student:			
Communication for different audiences *(e.g., peers, adults)* **and purposes** *(e.g., to inform, to persuade)* **in oral, visual, and/or written forms**	communicates for different audiences and purposes with limited effectiveness	communicates for different audiences and purposes with some effectiveness	communicates for different audiences and purposes with considerable effectiveness	communicates for different audiences and purposes with a high degree of effectiveness
Use of conventions, vocabulary, and terminology of the discipline in oral, visual, and/or written forms *(e.g., symbols, formulae, scientific notation, SI units)*	uses conventions, vocabulary, and terminology of the discipline with limited effectiveness	uses conventions, vocabulary, and terminology of the discipline with some effectiveness	uses conventions, vocabulary, and terminology of the discipline with considerable effectiveness	uses conventions, vocabulary, and terminology of the discipline with a high degree of effectiveness
Application – The use of knowledge and skills to make connections within and between various contexts				
	The student:			
Application of knowledge and skills *(e.g., concepts and processes, safe use of equipment, scientific investigation skills)* **in familiar contexts**	applies knowledge and skills in familiar contexts with limited effectiveness	applies knowledge and skills in familiar contexts with some effectiveness	applies knowledge and skills in familiar contexts with considerable effectiveness	applies knowledge and skills in familiar contexts with a high degree of effectiveness
Transfer of knowledge and skills *(e.g., concepts and processes, safe use of equipment, scientific investigation skills)* **to unfamiliar contexts**	transfers knowledge and skills to unfamiliar contexts with limited effectiveness	transfers knowledge and skills to unfamiliar contexts with some effectiveness	transfers knowledge and skills to unfamiliar contexts with considerable effectiveness	transfers knowledge and skills to unfamiliar contexts with a high degree of effectiveness
Making connections between science, technology, society, and the environment *(e.g., assessing the impact of science on technology, people and other living things, and the environment)*	makes connections between science, technology, society, and the environment with limited effectiveness	makes connections between science, technology, society, and the environment with some effectiveness	makes connections between science, technology, society, and the environment with considerable effectiveness	makes connections between science, technology, society, and the environment with a high degree of effectiveness
Proposing courses of practical action to deal with problems relating to science, technology, society, and the environment	proposes courses of practical action of limited effectiveness	proposes courses of practical action of some effectiveness	proposes courses of practical action of considerable effectiveness	proposes highly effective courses of practical action

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

EVALUATION AND REPORTING OF STUDENT ACHIEVEMENT

Student achievement must be communicated formally to students and parents by means of the Provincial Report Card, Grades 9–12. The report card provides a record of the student's achievement of the curriculum expectations in every course, at particular points in the school year or semester, in the form of a percentage grade. The percentage grade represents the quality of the student's overall achievement of the expectations for the course and reflects the corresponding level of achievement as described in the achievement chart for the discipline.

A final grade is recorded for every course, and a credit is granted and recorded for every course in which the student's grade is 50% or higher. The final grade for each course will be determined as follows:

- Seventy per cent of the grade will be based on evaluations conducted throughout the course. This portion of the grade should reflect the student's most consistent level of achievement throughout the course, although special consideration should be given to more recent evidence of achievement.
- Thirty per cent of the grade will be based on a final evaluation in the form of an examination, performance, essay, and/or other method of evaluation suitable to the course content and administered towards the end of the course.

REPORTING ON DEMONSTRATED LEARNING SKILLS

The report card provides a record of the learning skills demonstrated by the student in every course, in the following five categories: Works Independently, Teamwork, Organization, Work Habits, and Initiative. The learning skills are evaluated using a four-point scale (E–Excellent, G–Good, S–Satisfactory, N–Needs Improvement). The separate evaluation and reporting of the learning skills in these five areas reflects their critical role in students' achievement of the curriculum expectations. To the extent possible, the evaluation of learning skills, apart from any that may be included as part of a curriculum expectation in a course, should not be considered in the determination of percentage grades.

SOME CONSIDERATIONS FOR PROGRAM PLANNING

When planning a program in science, teachers must take into account considerations in a number of important areas, including those discussed below.

INSTRUCTIONAL APPROACHES

> *A much more effective way to learn is for students to be actively involved in thinking and discussing during both class and investigation activities, with the goal of having the students develop a deep understanding of scientific concepts.*
>
> Kathleen Falconer et al., *Effect of Reformed Courses in Physics and Physical Science on Student Conceptual Understanding* (American Educational Research Association, April 2001), p. 1

Students come to secondary school with a natural curiosity developed throughout the elementary grades. They also bring with them individual interests and abilities as well as diverse personal and cultural experiences, all of which have an impact on their prior knowledge about science, technology, the environment, and the world they live in. Effective instructional approaches and learning activities draw on students' prior knowledge, capture their interest, and encourage meaningful practice both inside and outside the classroom. Students will be engaged when they are able to see the connection between the scientific concepts they are learning and their application in the world around them and in real-life situations.

Students in a science class typically demonstrate diversity in the ways they learn best. It is important, therefore, that students have opportunities to learn in a variety of ways – individually, cooperatively, independently, with teacher direction, through hands-on experiences, and through examples followed by practice. In science, students are required to learn concepts and procedures, acquire skills, and learn and apply scientific processes, and they become competent in these various areas with the aid of instructional and learning strategies that are suited to the particular type of learning. The approaches and strategies teachers use will vary according to both the object of the learning and the needs of the students.

Differentiated Instruction is responsive instruction. It occurs as teachers become increasingly proficient in understanding their students as individuals, increasingly comfortable with the meaning and structure of the disciplines they teach, and increasingly expert at teaching flexibly in order to match instruction to student need with the goal of maximizing the potential of each learner in a given area.

Carol Ann Tomlinson, *Fulfilling the Promise of the Differentiated Classroom* (ASCD, 2003), pp. 2–3

In order to learn science and to apply their knowledge and skills effectively, students must develop a solid understanding of scientific concepts. Research and successful classroom practice have shown that an inquiry approach, with emphasis on learning through concrete, hands-on experiences, best enables students to develop the conceptual foundation they need. When planning science programs, teachers will provide activities and challenges that actively engage students in inquiries that honour the ideas and skills students bring to them, while further deepening their conceptual understandings and essential skills.

Students will investigate scientific concepts using a variety of equipment, materials, and strategies. Activities are necessary for supporting the effective learning of science by all students. These active learning opportunities invite students to explore and investigate abstract scientific ideas in rich, varied, and hands-on ways. Moreover, the use of a variety of equipment and materials helps deepen and extend students' understanding of scientific concepts and further extends their development of scientific investigation skills.

All learning, especially new learning, should be embedded in well-chosen contexts for learning – that is, contexts that are broad enough to allow students to investigate initial understandings, identify and develop relevant supporting skills, and gain experience with varied and interesting applications of the new knowledge. In the secondary science curriculum, many of these contexts come from the Relating Science to Technology, Society, and the Environment (STSE) expectations. Such rich contexts for learning enable students to see the "big ideas" of science. This understanding of "big ideas" will enable and encourage students to use scientific thinking throughout their lives. As well, contextualized teaching and learning provides teachers with useful insights into their students' thinking, their understanding of concepts, and their ability to reflect on what they have done. This insight allows teachers to provide supports to help enhance students' learning.

HEALTH AND SAFETY IN SCIENCE

Teachers must model safe practices at all times and communicate safety expectations to students in accordance with school board and Ministry of Education policies and Ministry of Labour regulations. Teachers are responsible for ensuring the safety of students during classroom activities and also for encouraging and motivating students to assume responsibility for their own safety and the safety of others. Teachers must also ensure that students have the knowledge and skills needed for safe participation in science activities.

To carry out their responsibilities with regard to safety, it is important for teachers to have:

- concern for their own safety and that of their students;
- the knowledge necessary to use the materials, equipment, and procedures involved in science safely;
- knowledge concerning the care of living things – plants and animals – that are brought into the classroom;
- the skills needed to perform tasks efficiently and safely.

Students demonstrate that they have the knowledge, skills, and habits of mind required for safe participation in science activities when they:

- maintain a well-organized and uncluttered work space;
- follow established safety procedures;
- identify possible safety concerns;
- suggest and implement appropriate safety procedures;
- carefully follow the instructions and example of the teacher;
- consistently show care and concern for their own safety and that of others.

Various kinds of health and safety issues can arise when learning involves field trips. Out-of-school field trips can provide an exciting and authentic dimension to students' learning experiences. They also take the teacher and students out of the predictable classroom environment and into unfamiliar settings. Teachers must preview and plan these activities carefully to protect students' health and safety.

PLANNING SCIENCE PROGRAMS FOR STUDENTS WITH SPECIAL EDUCATION NEEDS

Classroom teachers are the key educators of students who have special education needs. They have a responsibility to help all students learn, and they work collaboratively with special education resource teachers, where appropriate, to achieve this goal. *Special Education Transformation: The Report of the Co-Chairs with the Recommendations of the Working Table on Special Education, 2006* endorses a set of beliefs that should guide program planning for students with special education needs *in all disciplines*. These beliefs are as follows:

- All students can succeed.
- Universal design[2] and differentiated instruction[3] are effective and interconnected means of meeting the learning or productivity needs of any group of students.
- Successful instructional practices are founded on evidence-based research, tempered by experience.
- Classroom teachers are key educators for a student's literacy and numeracy development.
- Each student has his or her own unique patterns of learning.
- Classroom teachers need the support of the larger community to create a learning environment that supports students with special education needs.
- Fairness is not sameness.

In any given classroom, students may demonstrate a wide range of strengths and needs. Teachers plan programs that recognize this diversity and give students performance tasks that respect their particular abilities so that all students can derive the greatest possible benefit from the teaching and learning process. The use of flexible groupings for instruction and the provision of ongoing assessment are important elements of programs that accommodate a diversity of learning needs.

2. The goal of Universal Design for Learning (UDL) is to create a learning environment that is open and accessible to all students, regardless of age, skills, or situation. Instruction based on principles of universal design is flexible and supportive, can be adjusted to meet different student needs, and enables all students to access the curriculum as fully as possible.

3. Differentiated instruction is effective instruction that shapes each student's learning experience in response to his or her particular learning preferences, interests, and readiness to learn.

In planning science courses for students with special education needs, teachers should begin by examining the current achievement level of the individual student, the strengths and learning needs of the student, and the knowledge and skills that all students are expected to demonstrate at the end of the course, in order to determine which of the following options is appropriate for the student:

- no accommodations[4] or modifications; or
- accommodations only; or
- modified expectations, with the possibility of accommodations; or
- alternative expectations, which are not derived from the curriculum expectations for a course and which constitute alternative programs and/or courses.

If the student requires either accommodations or modified expectations, or both, the relevant information, as described in the following paragraphs, must be recorded in his or her Individual Education Plan (IEP). More detailed information about planning programs for students with special education needs, including students who require alternative programs and/or courses,[5] can be found in *The Individual Education Plan (IEP): A Resource Guide, 2004* (referred to hereafter as the *IEP Resource Guide, 2004*). For a detailed discussion of the ministry's requirements for IEPs, see *Individual Education Plans: Standards for Development, Program Planning, and Implementation, 2000* (referred to hereafter as *IEP Standards, 2000*). (Both documents are available at www.edu.gov.on.ca.)

Students Requiring Accommodations Only

Some students are able, with certain accommodations, to participate in the regular course curriculum and to demonstrate learning independently. Accommodations allow access to the course without any changes to the knowledge and skills the student is expected to demonstrate. The accommodations required to facilitate the student's learning must be identified in his or her IEP (see *IEP Standards, 2000*, page 11). A student's IEP is likely to reflect the same accommodations for many, or all, subjects or courses.

Providing accommodations to students with special education needs should be the first option considered in program planning. Instruction based on principles of universal design and differentiated instruction focuses on the provision of accommodations to meet the diverse needs of learners.

There are three types of accommodations:

- *Instructional accommodations* are changes in teaching strategies, including styles of presentation, methods of organization, or use of technology and multimedia.
- *Environmental accommodations* are changes that the student may require in the classroom and/or school environment, such as preferential seating or special lighting.
- *Assessment accommodations* are changes in assessment procedures that enable the student to demonstrate his or her learning, such as allowing additional time to complete tests or assignments or permitting oral responses to test questions (see page 29 of the *IEP Resource Guide, 2004*, for more examples).

4. *Accommodations* refers to individualized teaching and assessment strategies, human supports, and/or individualized equipment.

5. Alternative programs are identified on the IEP form by the term "alternative (ALT)".

If a student requires "accommodations only" in science courses, assessment and evaluation of his or her achievement will be based on the appropriate course curriculum expectations and the achievement levels outlined in this document. The IEP box on the student's Provincial Report Card will not be checked, and no information on the provision of accommodations will be included.

Students Requiring Modified Expectations

Some students will require modified expectations, which differ from the regular course expectations. For most students, modified expectations will be based on the regular course curriculum, with changes in the number and/or complexity of the expectations. Modified expectations represent specific, realistic, observable, and measurable achievements and describe specific knowledge and/or skills that the student can demonstrate independently, given the appropriate assessment accommodations.

It is important to monitor, and to reflect clearly in the student's IEP, the extent to which expectations have been modified. As noted in section 7.12 of the ministry's policy document *Ontario Secondary Schools, Grades 9 to 12: Program and Diploma Requirements, 1999*, the principal will determine whether achievement of the modified expectations constitutes successful completion of the course, and will decide whether the student is eligible to receive a credit for the course. This decision must be communicated to the parents and the student.

When a student is expected to achieve most of the curriculum expectations for the course, the modified expectations should identify *how the required knowledge and skills differ from those identified in the course expectations*. When modifications are so extensive that achievement of the learning expectations (knowledge, skills, and performance tasks) is not likely to result in a credit, the expectations should *specify the precise requirements or tasks on which the student's performance will be evaluated* and which will be used to generate the course mark recorded on the Provincial Report Card.

Modified expectations indicate the knowledge and/or skills the student is expected to demonstrate and have assessed in each reporting period (see *IEP Standards, 2000*, pages 10 and 11). The student's learning expectations must be reviewed in relation to the student's progress at least once every reporting period, and must be updated as necessary (see *IEP Standards, 2000*, page 11).

If a student requires modified expectations in science courses, assessment and evaluation of his or her achievement will be based on the learning expectations identified in the IEP and on the achievement levels outlined in this document. If some of the student's learning expectations for a course are modified but the student is working towards a credit for the course, it is sufficient simply to check the IEP box on the Provincial Report Card. If, however, the student's learning expectations are modified to such an extent that the principal deems that a credit will not be granted for the course, the IEP box must be checked and the appropriate statement from the *Guide to the Provincial Report Card, Grades 9–12, 1999* (page 8) must be inserted. The teacher's comments should include relevant information on the student's demonstrated learning of the modified expectations, as well as next steps for the student's learning in the course.

PROGRAM CONSIDERATIONS FOR ENGLISH LANGUAGE LEARNERS

Ontario schools have some of the most multilingual student populations in the world. The first language of approximately 20 per cent of the students in Ontario's English-language schools is a language other than English. Ontario's linguistic heritage includes several Aboriginal languages and many African, Asian, and European languages. It also includes some varieties of English – also referred to as dialects – that differ significantly from the English required for success in Ontario schools. Many English language learners were born in Canada and have been raised in families and communities in which languages other than English, or varieties of English that differ from the language used in the classroom, are spoken. Other English language learners arrive in Ontario as newcomers from other countries; they may have experience of highly sophisticated educational systems, or they may have come from regions where access to formal schooling was limited.

When they start school in Ontario, many of these students are entering a new linguistic and cultural environment. All teachers share in the responsibility for these students' English language development.

English language learners (students who are learning English as a second or additional language in English-language schools) bring a rich diversity of background knowledge and experience to the classroom. These students' linguistic and cultural backgrounds not only support their learning in their new environment but also become a cultural asset in the classroom community. Teachers will find positive ways to incorporate this diversity into their instructional programs and into the classroom environment.

Most English language learners in Ontario schools have an age-appropriate proficiency in their first language. Although they need frequent opportunities to use English at school, there are important educational and social benefits associated with continued development of their first language while they are learning English. Teachers need to encourage parents to continue to use their own language at home in rich and varied ways as a foundation for language and literacy development in English. It is also important for teachers to find opportunities to bring students' languages into the classroom, using parents and community members as a resource.

During their first few years in Ontario schools, English language learners may receive support through one of two distinct programs from teachers who specialize in meeting their language-learning needs:

English as a Second Language (ESL) programs are for students born in Canada or newcomers whose first language is a language other than English or is a variety of English significantly different from that used for instruction in Ontario schools.

English Literacy Development (ELD) programs are primarily for newcomers whose first language is a language other than English, or is a variety of English significantly different from that used for instruction in Ontario schools, and who arrive with significant gaps in their education. These students generally come from countries where access to education is limited or where there are limited opportunities to develop language and literacy skills in any language. Some Aboriginal students from remote communities in Ontario may also have had limited opportunities for formal schooling, and they also may benefit from ELD instruction.

In planning programs for students with linguistic backgrounds other than English, teachers need to recognize the importance of the orientation process, understanding that every learner needs to adjust to the new social environment and language in a unique way and at an individual pace. For example, students who are in an early stage of English-language acquisition may go through a "silent period" during which they closely observe the interactions and physical surroundings of their new learning environment. They may use body language rather than speech or they may use their first language until they have gained enough proficiency in English to feel confident of their interpretations and responses. Students thrive in a safe, supportive, and welcoming environment that nurtures their self-confidence while they are receiving focused literacy instruction. When they are ready to participate in paired, small-group, or whole-class activities, some students will begin by using a single word or phrase to communicate a thought, while others will speak quite fluently.

With exposure to the English language in a supportive learning environment, most young children will develop oral fluency quite quickly, making connections between concepts and skills acquired in their first language and similar concepts and skills presented in English. However, oral fluency is not a good indicator of a student's knowledge of vocabulary or sentence structure, reading comprehension, or other aspects of language proficiency that play an important role in literacy development and academic success. Research has shown that it takes five to seven years for most English language learners to catch up to their English-speaking peers in their ability to use English for academic purposes. Moreover, the older the children are when they arrive, the more language knowledge and skills they have to catch up on, and the more direct support they require from their teachers.

Responsibility for students' English-language development is shared by the classroom teacher, the ESL/ELD teacher (where available), and other school staff. Volunteers and peers may also be helpful in supporting English language learners in the language classroom. Teachers must adapt the instructional program in order to facilitate the success of these students in their classrooms. Appropriate adaptations include:

- modification of some or all of the subject expectations so that they are challenging but attainable for the learner at his or her present level of English proficiency, given the necessary support from the teacher;
- use of a variety of instructional strategies (e.g., extensive use of visual cues, graphic organizers, and scaffolding; previewing of textbooks; pre-teaching of key vocabulary; peer tutoring; strategic use of students' first languages);
- use of a variety of learning resources (e.g., visual material, simplified text, bilingual dictionaries, and materials that reflect cultural diversity);
- use of assessment accommodations (e.g., granting of extra time; use of oral interviews, demonstrations or visual representations, or tasks requiring completion of graphic organizers or cloze sentences instead of essay questions and other assessment tasks that depend heavily on proficiency in English).

When learning expectations in any course are modified for an English language learner (whether the student is enrolled in an ESL or ELD course or not), this information must be clearly indicated on the student's report card.

Although the degree of program adaptation required will decrease over time, students who are no longer receiving ESL or ELD support may still need some program adaptations to be successful.

For further information on supporting English language learners, refer to *The Ontario Curriculum, Grades 9 to 12: English as a Second Language and English Literacy Development, 2007; English Language Learners – ESL and ELD Programs and Services: Policies and Procedures for Ontario Elementary and Secondary Schools, Kindergarten to Grade 12, 2007*; and the resource guide *Many Roots, Many Voices: Supporting English Language Learners in Every Classroom, 2005*.

ENVIRONMENTAL EDUCATION

> *Environmental education is education about the environment, for the environment, and in the environment that promotes an understanding of, rich and active experience in, and an appreciation for the dynamic interactions of:*
>
> - *The earth's physical and biological systems*
> - *The dependency of our social and economic systems on these natural systems*
> - *The scientific and human dimensions of environmental issues*
> - *The positive and negative consequences, both intended and unintended, of the interactions between human-created and natural systems.*
>
> *Shaping Our Schools, Shaping Our Future: Environmental Education in Ontario Schools* (June 2007), p. 6

As noted in *Shaping Our Schools, Shaping Our Future: Environmental Education in Ontario Schools*, environmental education "is the responsibility of the entire education community. It is a content area and can be taught. It is an approach to critical thinking, citizenship, and personal responsibility, and can be modelled. It is a context that can enrich and enliven education in all subject areas, and offer students the opportunity to develop a deeper connection with themselves, their role in society, and their interdependence on one another and the earth's natural systems" (p. 10).

The increased emphasis on relating science to technology, society, and the environment (STSE) within this curriculum document provides numerous opportunities for teachers to integrate environmental education effectively into the curriculum. The STSE expectations provide meaningful contexts for applying what has been learned about the environment, for thinking critically about issues related to the environment, and for considering personal action that can be taken to protect the environment. Throughout the courses and strands, teachers have opportunities to take students out of the classroom and into the world beyond the school, to observe, explore, and investigate. One effective way to approach environmental literacy is through examining critical inquiry questions related to students' sense of place, to the impact of human activity on the environment, and/or to systems thinking. This can be done at numerous points within the science curriculum.

The following are some examples:

- A sense of place can be developed as students investigate the geological history of their region.
- An understanding of the effects of human activity on the environment can be developed as students consider the impact of their actions (e.g., the use of household chemicals, the consumption of electricity, the acquisition of new electronic devices and the disposal of used ones) on the local and global enrivonment.
- Systems thinking can be developed as students extend their understanding of various kinds of systems (e.g., bodily systems; our solar system; Earth systems; mechanical systems) and the interdependence of their components.

ANTIDISCRIMINATION EDUCATION

Overview

The implementation of antidiscrimination principles in education influences all aspects of school life. It promotes a school climate that encourages all students to work to attain high standards, affirms the worth of all students, and helps students strengthen their sense of identity and develop a positive self-image. It encourages staff and students alike to value and show respect for diversity in the school and the wider society. It requires schools to adopt measures to provide a safe environment for learning, free from harassment, violence, and expressions of hate.

Antidiscrimination education encourages students to think critically about themselves and others in the world around them in order to promote fairness, healthy relationships, and active, responsible citizenship.

Schools have the responsibility to ensure that school–community interaction reflects the diversity in the local community and wider society. Consideration should be given to a variety of strategies for communicating and working with parents and community members from diverse groups, in order to ensure their participation in such school activities as plays, concerts, and teacher interviews. Families new to Canada, who may be unfamiliar with the Ontario school system, or parents of Aboriginal students may need special outreach and encouragement in order to feel comfortable in their interactions with the school.

Antidiscrimination Education and Science

The science program provides students with access to materials that reflect diversity with respect to gender, race, culture, and ability. Diverse groups of people involved in scientific activities and careers should be prominently featured. In planning the science program, teachers should consider issues such as access to laboratory experiences and equipment. Laboratory benches and lighting should be adjustable and appropriate for students with physical disabilities. Equipment and materials can also be adapted in ways that make them accessible to all students.

The examples used to illustrate knowledge and skills, and the practical applications and topics that students explore as part of the learning process, should vary so that they appeal to both boys and girls and relate to students' diverse backgrounds, interests, and experiences.

In many instances, variations in culture and location (whether rural, urban, or suburban) can be found in a single classroom. Students living in apartment buildings will have different access to plants and animals than students living in a rural setting or on a First Nation reserve. There may be cultural sensitivities for some students in areas such as the use of biological specimens. For example, a number of religions have prohibitions regarding pigs. Although it is impossible to anticipate every contingency, teachers should be open to adjusting their instruction, if feasible, when concerns are brought to their attention.

It is important that learning activities include opportunities for students to describe, study, or research how women and men from a variety of backgrounds, including Aboriginal peoples, have contributed to science, used science to solve problems in their daily life and work, or been affected by scientific processes or phenomena. The agricultural practices of various cultures and the uses they have made of medicinal plants might be considered. Students might examine the impact of water pollution, resource extraction, or power generation on the health, lifestyles, and livelihoods of Aboriginal peoples. In addition, students might investigate ways in which grassroots organizations from different regions, and representing a range of social and cultural groups, have responded to environmental challenges. Expectations in the curriculum encourage students to look at the perspectives and world views of various cultures, including Aboriginal cultures, as they relate to scientific issues.

Access to computers should be monitored and a range of software applications provided. A problem-solving approach can benefit students who are having difficulties with materials or equipment. Because access to equipment at home will vary, it is important to offer challenges for or support to students whose levels of prior knowledge differ.

CRITICAL THINKING AND CRITICAL LITERACY IN SCIENCE

Critical thinking is the process of thinking about ideas or situations in order to understand them fully, identify their implications, and/or make a judgement about what is sensible or reasonable to believe or do. Critical thinking includes skills such as questioning, predicting, hypothesizing, analysing, synthesizing, examining opinions, identifying values and issues, detecting bias, and distinguishing between alternatives.

Students use critical thinking skills in science when they assess, analyse, and/or evaluate the impact of something on society and the environment; when they form an opinion about something and support that opinion with logical reasons; or when they create personal plans of action with regard to making a difference. In order to do these things, students need to examine the opinions and values of others, detect bias, look for implied meaning in their readings, and use the information gathered to form a personal opinion or stance.

As they work to achieve the STSE expectations, students are frequently asked to identify the implications of an action, activity, or process. As they gather information from a variety of sources, they need to be able to interpret what they are reading, to look for instances of bias, and to determine why that source might express that particular bias.

In developing the skills of scientific investigation (inquiry/research skills), students must ask appropriate questions to frame their research, interpret information, and detect bias. Depending on the topic, they may be required to consider the values and perspectives of a variety of groups and individuals.

Critical literacy is the capacity for a particular type of critical thinking that involves looking beyond the literal meaning of a text to determine what is present and what is missing, in order to analyse and evaluate the text's complete meaning and the author's intent. Critical literacy goes beyond conventional critical thinking by focusing on issues related to fairness, equity, and social justice. Critically literate students adopt a critical stance, asking what view of the world the text advances and whether they find this view acceptable.

In science, students who are critically literate are able, for example, to read or view reports from a variety of sources on a common issue. They are able to assess how fairly the facts have been reported, what biases might be contained in each report and why that might be, how the content of the report was determined and by whom, and what might have been left out of the report and why. These students would then be equipped to produce their own interpretation of the issue.

LITERACY, MATHEMATICAL LITERACY, AND INVESTIGATION (INQUIRY/RESEARCH) SKILLS

Literacy, mathematical literacy, and investigation skills are critical to students' success in all subjects of the curriculum and in all areas of their lives. Many of the activities and tasks that students undertake in the science curriculum involve the literacy skills related to oral, written, and visual communication. Communication skills are fundamental to the development of scientific literacy, and fostering students' communication skills is an important part of the teacher's role in the science curriculum.

When reading in science, students use a different set of skills than they do when reading fiction or general non-fiction. They need to understand vocabulary and terminology that are unique to science, and must be able to interpret symbols, charts, diagrams, and graphs. In addition, as they progress through secondary school, it becomes critically important for them to have the ability to make sense of the organization of science textbooks, scientific journals, and research papers. To help students construct meaning from scientific texts, it is essential that teachers of science model and teach the strategies that support learning to read while students are reading to learn in science.

Writing in science employs special forms and therefore also requires specific and focused learning opportunities. Students use writing skills to describe and explain their observations, to support the process of critically analysing information in both informal and formal contexts, and to present their findings in written, graphic, and multimedia forms.

> *Scientists…take meticulous notes to form hypotheses, document observations, conduct experiments, and solve problems. Writing for them is much more than data collection; it is exploring, revising, and thinking on paper. Writing helps them learn facts, work out what the facts mean, and use facts to make new discoveries and refine old theories.*
>
> Laura Robb, *Teaching Reading in Social Studies, Science and Math* (2003), p. 59

Oral communication skills are fundamental to the development of scientific literacy and are essential for thinking and learning. Through purposeful talk, students not only learn to communicate information but also explore and come to understand ideas and concepts; identify and solve problems; organize their experience and knowledge; and express and clarify their thoughts, feelings, and opinions.

To develop their oral communication skills, students need numerous opportunities to listen to information and talk about a range of subjects in science. The science program provides opportunities for students to engage in various oral activities in connection with expectations in all the strands, such as brainstorming to identify what they know about the new topic they are studying, discussing strategies for solving a problem, presenting and defending ideas or debating issues, and offering critiques of models and results produced by their peers.

Students' understanding is revealed through both oral and written communication. It is not always necessary for science learning to involve a written communication component. Whether students are talking or writing about their scientific learning, teachers can ask questions that prompt students to explain their thinking and reasoning behind a particular solution, design, or strategy, or to reflect on what they have done.

Understanding science also requires the use and understanding of specialized terminology. In all science courses, students are expected to use appropriate and correct terminology, and are encouraged to use language with care and precision in order to communicate effectively.

The Ministry of Education has facilitated the development of materials to support literacy instruction across the curriculum. Helpful advice for integrating literacy instruction in senior science courses may be found in *Think Literacy: Cross-Curricular Approaches, Grades 7–12, 2003.*

The science program also builds on, reinforces, and enhances mathematical literacy. For example, clear, concise communication in science often involves using diagrams, tables, graphs, calculations, and equations to represent quantitative data. Many components of the science curriculum emphasize students' ability to interpret data and information presented in a variety of forms (e.g., symbols, graphs, tables). In addition, physics, chemistry, earth and space science, and biology provide rich problem-solving situations that require students to apply, and help them develop and extend, mathematical knowledge and thinking.

Investigations are at the heart of learning in science. In science courses, students will have multiple opportunities to develop their ability to ask questions and conduct inquiries and research as they plan and carry out investigations. They will practise using a variety of inquiry and research skills that they need to carry out their investigations, and will learn how to determine the most appropriate methods to use in a particular inquiry or research activity. Students will also learn how to locate relevant information in a variety of print and electronic sources, including books and articles, scientific periodicals, manuals, newspapers, websites, databases, tables, diagrams, and charts. As they advance through the courses, students will be expected to distinguish between primary and secondary sources, to use these sources in appropriate ways and with increasing sophistication, and to assess their validity and relevance.

THE ROLE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY IN SCIENCE

Information and communications technology (ICT) provides a range of tools that can significantly extend and enrich teachers' instructional strategies and support students' learning in science. Computer programs can help students collect, organize, and sort the data they gather and to write, edit, and present multimedia reports on their findings. ICT can also be used to connect students to other schools, at home and abroad, and to bring the global community into the local classroom. Technology also makes it possible to use simulations – for instance, when field studies on a particular topic are not feasible or dissections are not acceptable.

Whenever appropriate, therefore, students should be encouraged to use ICT to support and communicate their learning. For example, students working individually or in groups can use computers and portable storage devices, CD-ROM and DVD technologies, and/or Internet websites to gain access to science institutions in Canada and around the world. Students can also use digital or video cameras to record laboratory inquiries or findings on field trips, or for multimedia presentations on scientific issues.

Although the Internet is a powerful learning tool, all students must be made aware of issues of privacy, safety, and responsible use, as well as of the potential for abuse of this technology, particularly when it is used to promote hatred.

ICT tools are also useful for teachers in their teaching practice, both for whole class instruction and for the design of curriculum units that contain varied approaches to learning to meet diverse student needs. A number of educational software programs to support science are licensed through the ministry and are listed at www.osapac.org/software.asp.

THE ONTARIO SKILLS PASSPORT AND ESSENTIAL SKILLS

Teachers planning programs in science need to be aware of the purpose and benefits of the Ontario Skills Passport (OSP). The OSP is a bilingual, web-based resource that enhances the relevance of classroom learning for students and strengthens school–work connections. The OSP provides clear descriptions of Essential Skills such as Reading Text, Writing, Computer Use, Measurement and Calculation, and Problem Solving and includes an extensive database of occupation-specific workplace tasks that illustrate how workers use these skills on the job. The Essential Skills are transferable, in that they are used in virtually all occupations. The OSP also includes descriptions of important work habits, such as working safely, being reliable, and providing excellent customer service. The OSP is designed to help employers assess and record students' demonstration of these skills and work habits during their cooperative education placements. Students can use the OSP to assess, practise, and build their Essential Skills and work habits and transfer them to a job or further education or training.

The skills described in the OSP are the Essential Skills that the Government of Canada and other national and international agencies have identified and validated, through extensive research, as the skills needed for work, learning, and life. These Essential Skills provide the foundation for learning all other skills and enable people to evolve with their jobs and adapt to workplace change. For further information on the OSP and the Essential Skills, visit http://skills.edu.gov.on.ca.

CAREER EDUCATION

Ongoing scientific discoveries and innovations 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 a variety of important capabilities, including the ability to identify issues, conduct research, carry out experiments, solve problems, present results, and work on projects both independently and as a team. Students are also given opportunities to explore various careers related to the areas of science under study and to research the education and training required for these careers (see the expectations in the first strand of every course in the program, "Scientific Investigation Skills and Career Exploration").

COOPERATIVE EDUCATION AND OTHER FORMS OF EXPERIENTIAL LEARNING

Cooperative education and other forms of experiential learning, such as job shadowing, field trips, and work experience, enable students to apply the skills they have developed in the classroom to real-life activities in the world of science and innovation. Cooperative education and other workplace experiences also help to broaden students' knowledge of employment opportunities in a wide range of fields, including laboratory technology and research, health care, veterinary science, and horticulture. In addition, students develop their understanding of workplace practices, certifications, and the nature of employer–employee relationships. Teachers of science can support their students' learning by maintaining links with community-based organizations to ensure that students have access to hands-on experiences that will reinforce the knowledge and skills they have gained in school.

Students who choose a science course as the related course for two cooperative education credits are able, through this packaged program, to meet the OSSD compulsory credit requirements for groups 1, 2, and 3.

Health and safety issues must be addressed when learning involves cooperative education and other workplace experiences. Teachers who provide support for students in workplace learning placements need to assess placements for safety and ensure that students understand the importance of issues relating to health and safety in the workplace. Before taking part in workplace learning experiences, students must acquire the knowledge and skills needed for safe participation. Students must understand their rights to privacy and confidentiality as outlined in the Freedom of Information and Protection of Privacy Act. They have the right to function in an environment free from abuse and harassment, and they need to be aware of harassment and abuse issues in establishing boundaries for their own personal safety. They should be informed about school and community resources and school policies and reporting procedures with respect to all forms of abuse and harassment.

Policy/Program Memorandum No. 76A,"Workplace Safety and Insurance Coverage for Students in Work Education Programs" (September 2000), outlines procedures for ensuring the provision of Health and Safety Insurance Board coverage for students who are at least 14 years of age and are on placements of more than one day. (A one-day job shadowing or job twinning experience is treated as a field trip.) Teachers should also be aware of the minimum age requirements outlined in the Occupational Health and Safety Act for persons to be in or to be working in specific workplace settings. All cooperative education and other workplace experiences will be provided in accordance with the ministry's policy document *Cooperative Education and Other Forms of Experiential Learning: Policies and Procedures for Ontario Secondary Schools, 2000*.

PLANNING PROGRAM PATHWAYS AND PROGRAMS LEADING TO A SPECIALIST HIGH SKILLS MAJOR

Science courses are well suited for inclusion in some programs leading to a Specialist High Skills Major (SHSM) or in programs designed to provide pathways to particular apprenticeship or workplace destinations. In some SHSM programs, science courses can be bundled with other courses to provide the academic knowledge and skills important to particular industry sectors and required for success in the workplace and postsecondary education, including apprenticeship. Science courses may also be combined with cooperative education credits to provide the workplace experience required for some SHSM programs and for various program pathways to apprenticeship and workplace destinations. (SHSM programs would also include sector-specific learning opportunities offered by employers, skills-training centres, colleges, and community organizations.)

BIOLOGY

Biology, Grade 11

University Preparation SBI3U

This course furthers students' understanding of the processes that occur in biological systems. Students will study theory and conduct investigations in the areas of biodiversity; evolution; genetic processes; the structure and function of animals; and the anatomy, growth, and function 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

Big Ideas

Diversity of Living Things

- All living things can be classified according to their anatomical and physiological characteristics.
- Human activities affect the diversity of living things in ecosystems.

Evolution

- Evolution is the process of biological change over time based on the relationships between species and their environments.
- The theory of evolution is a scientific explanation based on a large accumulation of evidence.
- Technology that enables humans to manipulate the development of species has economic and environmental implications.

Genetic Processes

- Genetic and genomic research can have social and environmental implications.
- Variability and diversity of living organisms result from the distribution of genetic materials during the process of meiosis.

Animals: Structure and Function

- Groups of organs with specific structures and functions work together as systems, which interact with other systems in the body.
- The development and uses of technology to maintain human health are based, in part, on the changing needs of society.

Plants: Anatomy, Growth, and Function

- Plants have specialized structures with distinct functions that enable them to respond and adapt to their environment.
- Plant variety is critical to the survival and sustainability of ecosystems.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Diversity of Living Things	Evolution	Genetic Processes	Animals: Structure and Function	Plants: Anatomy, Growth, and Function
Matter	✓				
Energy	✓			✓	
Systems and Interactions	✓	✓		✓	✓
Structure and Function	✓	✓	✓	✓	✓
Sustainability and Stewardship	✓	✓			✓
Change and Continuity	✓	✓	✓		

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., sampling instruments, a microscope, a stethoscope, dissection instruments) and materials (e.g., dichotomous keys, computer simulations, plant cuttings), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory and biological materials (e.g., preserved specimens); and by using appropriate personal protection

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation (e.g., biological diagrams, Punnett squares), and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., zoologist, botanist, geneticist, ecologist, pharmacologist, farmer, forester, horticulturalist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Colin D'Cunha, Louis Bernatchez, Lap-Chee Tsui, Helen Battle, Memory Elvin-Lewis), to the fields under study

B. DIVERSITY OF LIVING THINGS

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse the effects of various human activities on the diversity of living things;

B2. investigate, through laboratory and/or field activities or through simulations, the principles of scientific classification, using appropriate sampling and classification techniques;

B3. demonstrate an understanding of the diversity of living organisms in terms of the principles of taxonomy and phylogeny.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse some of the risks and benefits of human intervention (e.g., tree plantations; monoculture of livestock or agricultural crops; overharvesting of wild plants for medicinal purposes; using pesticides to control pests; suppression of wild fires) to the biodiversity of aquatic or terrestrial ecosystems [AI, C]

Sample issue: Stocking lakes with fish provides recreation for fishing enthusiasts and increases the amount of food available for humans and other animals. However, this practice also increases the competition for food, which could threaten native species and affect the natural biodiversity of the aquatic ecosystem.

Sample questions: What types of conservation efforts have been made to help protect local wetlands from urban developments? In what ways does the planting of native species in a disturbed area help to improve the ecosystem? How and why might some species benefit from human intervention?

B1.2 analyse the impact that climate change might have on the diversity of living things (e.g., rising temperatures can result in habitat loss or expansion; changing rainfall levels can cause drought or flooding of habitats) [AI, C]

Sample issue: Some scientists believe that we are in the early stages of a human-made mass extinction partly caused by rapid climate change. Many species that cannot tolerate the change will become extinct. However, Earth's history has shown that extinction of some species creates opportunities for surviving species to adapt, evolve, and flourish.

Sample questions: Why do higher temperatures affect the survival of some species in freshwater environments? Why would an increase in ocean temperatures endanger many species that depend on coral as a home and food supply? In what ways have longer growing seasons, which may include a second harvest, affected the biodiversity of agricultural lands? How might species such as the Eastern Massasauga rattlesnake be affected by increased water levels in their habitats?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to biodiversity, including, but not limited to: *genetic diversity, species diversity, structural diversity, protists, bacteria, fungi, binomial nomenclature,* and *morphology* [C]

B2.2 classify, and draw biological diagrams of, representative organisms from each of the kingdoms according to their unifying and distinguishing anatomical and physiological characteristics (e.g., vertebrate or invertebrate organisms, vascular or nonvascular plants) [PR, AI, C]

B2.3 use proper sampling techniques to collect various organisms from a marsh, pond, field, or other ecosystem, and classify the organisms according to the principles of taxonomy [PR, AI, C]

B2.4 create and apply a dichotomous key to identify and classify organisms from each of the kingdoms [PR, AI, C]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 explain the fundamental principles of taxonomy and phylogeny by defining concepts of taxonomic rank and relationship, such as genus, species, and taxon

B3.2 compare and contrast the structure and function of different types of prokaryotes, eukaryotes, and viruses (e.g., compare and contrast genetic material, metabolism, organelles, and other cell parts)

B3.3 describe unifying and distinguishing anatomical and physiological characteristics (e.g., types of reproduction, habitat, general physical structure) of representative organisms from each of the kingdoms

B3.4 explain key structural and functional changes in organisms as they have evolved over time (e.g., the evolution of eukaryotes from prokaryotes, of plants from unicellular organisms)

B3.5 explain why biodiversity is important to maintaining viable ecosystems (e.g., biodiversity helps increase resilience to stress and resistance to diseases or invading species)

C. EVOLUTION

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse the economic and environmental advantages and disadvantages of an artificial selection technology, and evaluate the impact of environmental changes on natural selection and endangered species;

C2. investigate evolutionary processes, and analyse scientific evidence that supports the theory of evolution;

C3. demonstrate an understanding of the theory of evolution, the evidence that supports it, and some of the mechanisms by which it occurs.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse, on the basis of research, the economic and environmental advantages and disadvantages of an artificial selection technology (e.g., livestock and horticultural breeding) [IP, PR, AI, C]

Sample issue: Selective breeding of agricultural crops can benefit populations in less-developed countries by producing hardier crops, increasing food supplies, and improving the nutritional content of food. However, opponents of artificial selection technology believe that it affects the natural ability of a species to reproduce, which negatively affects biodiversity.

Sample questions: How has selective breeding of specific crops helped to increase the yield of the crop and decrease the need for chemicals in the fields? How has the introduction of genetically engineered species in the horticultural industry affected other species planted in the same areas? In what ways do the characteristics of today's farm animals, such as cattle, pigs, and chickens, differ from those of earlier farm animals? What are the reasons for the differences?

C1.2 evaluate the possible impact of an environmental change on natural selection and on the vulnerability of species (e.g., adaptation to environmental changes can affect reproductive success of an organism) [AI, C]

Sample issue: An increase in forest fires in some areas of North America has affected the reproductive success of some species as their food supplies decrease and they are forced to adapt to adverse habitat conditions. Yet, forest fires also naturally promote changes in plant and animal species over time as the environment becomes more suitable for other species.

Sample questions: Why has a decline in the milkweed population, as a result of urbanization and pesticides, affected the migration of monarch butterflies? How has the introduction of bacteria and viruses in inland lakes affected the life cycle of carp? What impact has the loss of bamboo forests to urbanization had on the giant panda's ability to breed and live?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to evolution, including, but not limited to: *extinction, natural selection, phylogeny, speciation, niche, mutation, mimicry, adaptation,* and *survival of the fittest* [C]

C2.2 use a research process to investigate some of the key factors that affect the evolutionary process (e.g., genetic mutations, selective pressures, environmental stresses) [IP, PR]

C2.3 analyse, on the basis of research, and report on the contributions of various scientists to modern theories of evolution (e.g., Charles Lyell, Thomas Malthus, Jean-Baptiste Lamarck, Charles Darwin, Stephen Jay Gould, Niles Eldredge) [IP, PR, AI, C]

C2.4 investigate, through a case study or computer simulation, the processes of natural selection and artificial selection (e.g., selective breeding, antibiotic resistance in microorganisms), and analyse the different mechanisms by which they occur [PR, AI, C]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 explain the fundamental theory of evolution, using the evolutionary mechanism of natural selection to illustrate the process of biological change over time

C3.2 explain the process of adaptation of individual organisms to their environment (e.g., some disease-causing bacteria in a bacterial population can survive exposure to antibiotics due to slight genetic variations from the rest of the population, which allows successful surviving bacteria to pass on antibiotic resistance to the next generation)

C3.3 define the concept of speciation, and explain the process by which new species are formed

C3.4 describe some evolutionary mechanisms (e.g., natural selection, artificial selection, sexual selection, genetic variation, genetic drift, biotechnology), and explain how they affect the evolutionary development and extinction of various species (e.g., Darwin's finches, giraffes, pandas)

D. GENETIC PROCESSES

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. evaluate the importance of some recent contributions to our knowledge of genetic processes, and analyse social and ethical implications of genetic and genomic research;

D2. investigate genetic processes, including those that occur during meiosis, and analyse data to solve basic genetics problems involving monohybrid and dihybrid crosses;

D3. demonstrate an understanding of concepts, processes, and technologies related to the transmission of hereditary characteristics.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse, on the basis of research, some of the social and ethical implications of research in genetics and genomics (e.g., genetic screening, gene therapy, in vitro fertilization) [IP, PR, AI, C]

Sample issue: Gene therapy is a promising treatment for some inherited disorders such as cystic fibrosis. However, the technique remains risky and unproven, and there are ethical questions associated with its use and related research.

Sample questions: What are the possible social benefits of applications of stem-cell research? What ethical issues does such research raise? Why is the prospect of using genetically engineered material in human subjects controversial? What are some of the ethical issues related to gene therapy?

D1.2 evaluate, on the basis of research, the importance of some recent contributions to knowledge, techniques, and technologies related to genetic processes (e.g., research into the cystic fibrosis gene; the use of safflowers to produce insulin for human use) [IP, PR, AI, C]

Sample issue: Cancer researchers use bioinformatics and computational biology to study different types of cancer in an attempt to lower the risk of people who have a genetic predisposition to the disease. A risk is that this information could also be used to deny insurance coverage or payment of claims.

Sample questions: How has the human genome project allowed genetic research to move from a wet science to a dry science? How has the study of the copy number alteration of genes, conducted at the Hospital for Sick Children, helped researchers to understand genetic susceptibility to autism spectrum disorders? How has genomic research increased our understanding of human health and diseases?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to genetic processes, including, but not limited to: *haploid, diploid, spindle, synapsis, gamete, zygote, heterozygous, homozygous, allele, plasmid, trisomy, non-disjunction,* and *somatic cell* [C]

D2.2 investigate the process of meiosis, using a microscope or similar instrument, or a computer simulation, and draw biological diagrams to help explain the main phases in the process [PR, AI, C]

D2.3 use the Punnett square method to solve basic genetics problems involving monohybrid crosses, incomplete dominance, codominance, dihybrid crosses, and sex-linked genes [PR, AI, C]

D2.4 investigate, through laboratory inquiry or computer simulation, monohybrid and dihybrid crosses, and use the Punnett square method and probability rules to analyse the qualitative and quantitative data and determine the parent genotype [PR, AI, C]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the phases in the process of meiosis in terms of cell division, the movement of chromosomes, and crossing over of genetic material

D3.2 explain the concepts of DNA, genes, chromosomes, alleles, mitosis, and meiosis, and how they account for the transmission of hereditary characteristics according to Mendelian laws of inheritance

D3.3 explain the concepts of genotype, phenotype, dominance, incomplete dominance, codominance, recessiveness, and sex linkage according to Mendelian laws of inheritance

D3.4 describe some genetic disorders caused by chromosomal abnormalities (e.g., non-disjunction of chromosomes during meiosis) or other genetic mutations in terms of chromosomes affected, physical effects, and treatments

D3.5 describe some reproductive technologies (e.g., cloning, artificial insemination, in vitro fertilization, recombinant DNA), and explain how their use can increase the genetic diversity of a species (e.g., farm animals, crops)

E. ANIMALS: STRUCTURE AND FUNCTION

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse the relationships between changing societal needs, technological advances, and our understanding of internal systems of humans;

E2. investigate, through laboratory inquiry or computer simulation, the functional responses of the respiratory and circulatory systems of animals, and the relationships between their respiratory, circulatory, and digestive systems;

E3. demonstrate an understanding of animal anatomy and physiology, and describe disorders of the respiratory, circulatory, and digestive systems.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 evaluate the importance of various technologies, including Canadian contributions, to our understanding of internal body systems (e.g., endoscopes can be used to locate, diagnose, and surgically remove digestive system tumours; lasers can be used during surgery to destroy lung tumours; nuclear magnetic resonance [NMR] imaging can be used to diagnose injuries and cardiovascular disorders, such as aneurysms) [AI, C]

Sample issue: Magnetic resonance imaging (MRI) and computerized tomography (CT) are non-invasive imaging technologies that can produce three-dimensional views of organs, tissues, and bones, providing valuable information on internal body systems. The imaging equipment is expensive to buy, operate, and maintain, so it is usually available only in large urban centres with high demand.

Sample questions: How has the development of the two-photon imaging microscope improved our ability to locate and analyse rare types of cancerous cells? How are nanotechnologies being used in non-invasive exploratory surgeries? What are the benefits of new computer software that allows doctors to view three-dimensional models of organs for surgery and radiation treatments?

E1.2 assess how societal needs (e.g., the need for healthy foods; the need to counteract the effects of sedentary lifestyles) lead to scientific and technological developments related to internal systems (e.g., advances in dietary products and fitness equipment; improved standards for transplanting organs) [AI, C]

Sample issue: Diabetes is becoming a more common medical condition in Canada as a result of increasingly sedentary lifestyles and an aging population. Until recently, people with diabetes had to monitor their blood sugar and self-administer insulin. For many people, this regimen is now being replaced with more convenient and reliable insulin pump therapy.

Sample questions: How has the need to develop safer and faster tests for diagnosing internal diseases led to the development of nanotechnologies? What types of products have resulted from society's demand for multifunctional foods, such as low-calorie junk foods? What types of technologies have been developed in response to the shortage of organs available for transplant?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to animal anatomy, including, but not limited to: *systolic, diastolic, diffusion gradient, inhalation, exhalation, coronary, cardiac, ulcer, asthma,* and *constipation* [C]

E2.2 perform a laboratory or computer-simulated dissection of a representative animal, or use a mounted anatomical model, to analyse the relationships between the respiratory, circulatory, and digestive systems [PR, AI]

E2.3 use medical equipment (e.g., a stethoscope, a sphygmomanometer) to monitor the functional responses of the respiratory and circulatory systems to external stimuli (e.g., measure the change in breathing rate and heart rate after exercise) [PR, AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 explain the anatomy of the respiratory system and the process of ventilation and gas exchange from the environment to the cell (e.g., the movement of oxygen from the atmosphere to the cell; the roles of ventilation, hemoglobin, and diffusion in gas exchange)

E3.2 explain the anatomy of the digestive system and the importance of digestion in providing nutrients needed for energy and growth (e.g., the body's mechanical and chemical processes digest food, which provides the proteins needed to build muscle, and the fibre, water, vitamins, and minerals needed to regulate body processes)

E3.3 explain the anatomy of the circulatory system (e.g., blood components, blood vessels, the heart) and its function in transporting substances that are vital to health

E3.4 describe some disorders related to the respiratory, digestive, and circulatory systems (e.g., asthma, emphysema, ulcers, colitis, cardiac arrest, arteriosclerosis)

F. PLANTS: ANATOMY, GROWTH, AND FUNCTION

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. evaluate the importance of sustainable use of plants to Canadian society and other cultures;

F2. investigate the structures and functions of plant tissues, and factors affecting plant growth;

F3. demonstrate an understanding of the diversity of vascular plants, including their structures, internal transport systems, and their role in maintaining biodiversity.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 evaluate, on the basis of research, the importance of plants to the growth and development of Canadian society (e.g., as a source of food, pharmaceuticals, Aboriginal medicines, building materials, flood and erosion control; as a resource for recreation and ecotourism) [IP, PR, AI, C]

Sample issue: The agricultural sector holds great economic potential as demand increases for products such as biofuels, biochemicals, and biopharmaceuticals. Bioresources could also support our efforts to produce renewable energy, improve health, and minimize environmental impact. However, critics are concerned about the impact of bioresources on the availability of food crops and the price of food.

Sample questions: In what ways does the local-food movement contribute to community development? How does the re-introduction of native plant species along river banks help to prevent land erosion? What plant species are considered important in sustaining Canada's growth in the agricultural sector? How might the increasing demand for straw-bale housing materials support Canada's agricultural sector and increase the sustainability of other natural resources?

F1.2 evaluate, on the basis of research, ways in which different societies or cultures have used plants to sustain human populations while supporting environmental sustainability (e.g., sustainable agricultural practices in developing countries such as crop rotation and seed saving; traditional Aboriginal corn production practices) [IP, PR, AI, C]

Sample issue: Aboriginal peoples living near Canada's boreal forest rely on forest plants for food and medicine. Plants are harvested by traditional methods to maintain natural habitats and local biodiversity. However, these traditional practices are threatened as more areas are subject to development and commercial resource exploitation.

Sample questions: How are strategies for the conservation and sustainable use of medicinal plants being used by small communities and traditional healers in some developing countries? What effect does the re-establishment of wetland plants in agricultural settings have on the natural balance of the ecosystem? How are plants being used to clean wastewater from fish farms so that the water can go back into local streams?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to plants, including, but not limited to: *mesophyll*, *palisade*, *aerenchyma*, *epidermal tissue*, *stomata*, *root hair*, *pistil*, *stamen*, *venation*, *auxin*, and *gibberellin* [C]

F2.2 design and conduct an inquiry to determine the factors that affect plant growth (e.g., the effects on plant growth of the quantity of nutrients, the quantity and quality of light, and factors such as temperature and water retention or percolation rate) [IP, PR, AI]

F2.3 identify, and draw biological diagrams of, the specialized plant tissues in roots, stems, and leaves (e.g., xylem, phloem), using a microscope and models [PR, AI]

F2.4 investigate various techniques of plant propagation (e.g., leaf cutting, stem cutting, root cutting, seed germination) [PR]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 describe the structures of the various types of tissues in vascular plants, and explain the mechanisms of transport involved in the processes by which materials are distributed throughout a plant (e.g., transpiration, translocation, osmosis)

F3.2 compare and contrast monocot and dicot plants in terms of their structures (e.g., seeds, stem, flower, root) and their evolutionary processes (i.e., how one type evolved from the other)

F3.3 explain the reproductive mechanisms of plants in natural reproduction and artificial propagation (e.g., germination of seeds, leaf cuttings, grafting of branches onto a host tree)

F3.4 describe the various factors that affect plant growth (e.g., growth regulators, sunlight, water, nutrients, acidity, tropism)

F3.5 explain the process of ecological succession, including the role of plants in maintaining biodiversity and the survival of organisms after a disturbance to an ecosystem

Biology, Grade 11

SBI3C

This course focuses on the processes that occur in biological systems. Students will learn concepts and theories as they conduct investigations in the areas of cellular biology, microbiology, genetics, the anatomy of mammals, and the structure of plants and their role in the natural environment. 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

Big Ideas

Cellular Biology

- Life processes are determined by the structures and functions of biochemical compounds, cell organelles, and body systems.
- Technological devices that support cellular functions and processes can be used to improve human health.
- Substances that are present in our everyday lives can affect cellular functions and processes in positive and negative ways.

Microbiology

- Groups of microorganisms have common characteristics, and these characteristics enable them to interact with other organisms in the environment
- Microorganisms can have both positive and negative effects on the environment.
- The technological use of microorganisms raises many ethical issues.

Genetics

- Genetic research and biotechnology have social, environmental, and ethical implications.
- Variability and diversity of living organisms result from the distribution of genetic materials during the process of meiosis.

Anatomy of Mammals

- Groups of organs with specific structures and functions work together as systems, which interact with other systems in the body.
- Technologies that are used to maintain human health have social and economic benefits and costs.
- Environmental factors, including natural factors and those resulting from human activity, can have a wide range of effects on human health.

Plants in the Natural Environment

- Plants have specialized structures with distinct functions that enable them to respond and adapt to their environment.
- Plants are critical to the survival of ecosystems.
- Humans affect the sustainability of ecosystems when they alter the balance of plants within those ecosystems.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Cellular Biology	Microbiology	Genetics	Anatomy of Mammals	Plants in the Natural Environment
Matter	✓				
Energy	✓				
Systems and Interactions		✓		✓	
Structure and Function	✓	✓	✓	✓	✓
Sustainability and Stewardship		✓			✓
Change and Continuity			✓		✓

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

B2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., a microscope, a stethoscope, plant-propagation instruments, dissection instruments) and materials (e.g., prepared slides, agar plates, plants), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory and biological materials (e.g., preserved specimens); and by using appropriate personal protection

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation (e.g., biological diagrams, Punnett squares), and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places and significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., food science technologist, medical laboratory technologist, dental hygienist, outpost clinic/primary care nurse, respiratory therapist, veterinary technician, water or wastewater technician) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Julia Levy, Charles Beer, Shirley Tilghman, Walter Lewis, Gail Anderson), to the fields under study

B. CELLULAR BIOLOGY

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. evaluate the impact of environmental factors and medical technologies on certain cellular processes that occur in the human body;

B2. investigate the structures and functions of cells, and the factors that influence cellular activity, using appropriate laboratory equipment and techniques;

B3. demonstrate an understanding of the basic processes of cellular biology.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 evaluate the effectiveness of medical devices and technologies that are intended to aid cellular functions or processes (e.g., insulin infusion pump, chemotherapy) [AI, C]

Sample issue: For many people with diabetes, insulin pump therapy has replaced multiple daily insulin injections. The pump dispenses accurate doses of insulin and achieves reliable blood sugar control. However, not all jurisdictions fund the pump for all diabetics, and some people prefer self-administered injections to being hooked up to a machine.

Sample questions: How can stem cells be used in the treatment of leukemia? How effective is this type of treatment? Why is laser technology more effective than conventional surgery in removing cancerous tumours? What are some of the effects of kidney dialysis on the renal system and other body systems? What are the advantages of using nanotechnologies in the imaging and diagnosis of cellular abnormalities?

B1.2 analyse the effects of environmental factors on cellular processes that occur in the human body (e.g., the effect of lead on nerve cells; the effect of electromagnetic radiation on brain cells) [AI, C]

Sample issue: Vitamin D, essential to cellular processes that ensure the health of the bones and teeth, is not well absorbed by the human digestive system. It is manufactured by the body after exposure to the ultraviolet radiation of the sun. However, long-term exposure to the sun without proper UVA and UVB sunscreen protection can eventually lead to skin cancers, such as melanoma.

Sample questions: How might ingesting a high level of mercury by eating contaminated fish affect the nerve cells in our bodies? Which chemicals that are sometimes found in drinking water can affect the cells of the reproductive system? What are their possible effects? How can ultraviolet light from the sun affect the cells of the human eye? What types of toxins accumulate in human cells? What is their long-term effect on the body?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to cellular biology, including, but not limited to: *macromolecule*, *passive transport*, *active transport*, *catalyst*, and *fluid mosaic model* [C]

B2.2 investigate the effect of various qualitative factors (e.g., temperature) on the rate of diffusion of molecules across a plasma membrane [PR, AI]

B2.3 using a light microscope, identify visible organelles of a plant cell in a wet mount and an animal cell from a prepared slide, produce an accurate labelled drawing of each cell, and calculate and properly express the magnification of each image [PR, AI, C]

B2.4 investigate the effects of various qualitative factors on the action of enzymes (e.g., the effect of temperature or pH on the breakdown of starch by salivary enzymes) [PR, AI]

B2.5 conduct biological tests to identify biochemical compounds found in various food samples (e.g., use a biuret solution to test for proteins in samples of gelatin and albumin), and compare the biochemical compounds found in each food to those found in the others [PR, AI]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 describe the structures and functions of important biochemical compounds, including carbohydrates, proteins, enzymes, and lipids

B3.2 explain the roles of various organelles, including lysosomes, vacuoles, mitochondria, cell membranes, ribosomes, the endoplasmic reticulum, and Golgi bodies, in the processes of digestion, cellular respiration, and protein synthesis

B3.3 explain the chemical changes and energy transformations associated with the process of cellular respiration, and compare the reactants (i.e., glucose, oxygen) to the products (i.e., water, carbon dioxide, ATP)

B3.4 explain the importance of various cellular processes in human systems (e.g., enzymes act as biological catalysts to regulate chemical processes in the cells of the digestive system)

C. MICROBIOLOGY

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. assess the effects of microorganisms in the environment, and analyse ethical issues related to their use in biotechnology;

C2. investigate the development and physical characteristics of microorganisms, using appropriate laboratory equipment and techniques;

C3. demonstrate an understanding of the diversity of microorganisms and the relationships that exist between them.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 assess some of the effects, both beneficial and harmful, of microorganisms in the environment (e.g., decomposers break down waste, E. coli in water systems poses a severe risk to human health) [AI, C]

Sample issue: Adding beneficial microorganisms to compost at large-scale composting facilities aids in the decomposition of organic waste, and produces high-quality compost in a reduced amount of time. However, the microorganisms can leach into groundwater and run off into nearby water systems, where they can harm other organisms.

Sample questions: In what ways are nitrogen-fixing bacteria beneficial to plants but harmful to other organisms? How can microorganisms that have symbiotic relationships with some organisms be harmful to other organisms?

C1.2 analyse ethical issues related to the use of microorganisms in biotechnology (e.g., with respect to the use of bacterial insecticides, the patenting of modified microorganisms) [AI, C]

Sample issue: Genetically modified microorganisms are used in many biotechnological applications that benefit humans, in areas such as food production, the development of antibiotics and vaccines, and waste disposal. However, some of the same techniques could be used to manipulate microorganisms to create rapidly reproducing drug-resistant superbugs for use as bioweapons.

Sample questions: Should suppliers be required to label foods that have been modified using microorganisms, so that consumers can make more informed decisions about the food they eat? Why or why not? What do we know about the side effects and possible long-term effects of the medical and cosmetic uses of botulinum toxin? Do you think the use of this substance is adequately regulated?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to microbiology, including, but not limited to: *fission, conjugation, phage, dormancy, morphology, mycelium, spore, pathogen,* and *plasmid* [C]

C2.2 compare and contrast the cell structures of eukaryotes such as fungi, protozoa, and algae [PR, AI]

C2.3 prepare a laboratory culture of microorganisms (e.g., acidophilus) on agar, using proper aseptic techniques [PR]

C2.4 investigate the effect of antibacterial agents on different bacterial cultures (e.g., the effects of antibacterial soap or mouthwash on a bacterial culture) [PR]

C2.5 investigate and analyse the conditions (e.g., optimal temperature) needed by microorganisms for growth [PR, AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 describe the anatomy and morphology of various groups of microorganisms (e.g., eukaryotes, prokaryotes, viruses)

C3.2 explain the differences between the life cycles of eukaryotic and prokaryotic microorganisms in terms of cell division

C3.3 explain the vital roles of microorganisms in symbiotic relationships with other organisms (e.g., gut bacteria in cows digest cellulose; mycorrhizal fungi penetrate and effectively extend a plant's root system)

C3.4 explain the different methods of reproduction in various types of bacteria, viruses, and fungi

C3.5 describe how different viruses, bacteria, and fungi can affect host organisms, and how those effects are normally treated or prevented (e.g., hepatitis viruses can damage the liver, but vaccinations can prevent infections; streptococcus bacteria can cause respiratory infections, which are treated with antibiotics; ringworm is a fungal infection of the skin, treated with fungicides)

D. GENETICS

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. evaluate some social, ethical, and environmental implications of genetic research and related technologies;

D2. investigate the process of meiosis, and analyse data related to the laws of heredity;

D3. demonstrate an understanding of the process of meiosis, and explain the role of genes in the transmission of hereditary characteristics.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 evaluate, on the basis of research, some of the social and ethical implications of genetic research and reproductive technologies (e.g., sex selection, harvesting umbilical cord cells) [IP, PR, AI, C]

Sample issue: Scientists are using genetically modified embryonic stem cells to study the role of specific genes in human development and aging and the genetic causes of disease. Some people are concerned that these techniques could one day be used to "design" babies with certain desirable traits, creating a class of genetically enriched individuals and an inequitable society.

Sample questions: Who owns and controls our personal genetic information? Who should have access to our personal genetic information and decide how it will be used? Why is it important to regulate research into, and uses of, genetically based reproductive technologies? What are the ethical implications of using medical data from isolated communities (e.g., First Nations communities, homogeneous island communities) to study the genetic makeup of these communities without their knowledge and/or consent?

D1.2 evaluate, on the basis of research, some of the effects of genetic research and biotechnology (e.g., genetically modified organisms [GMOs]) on the environment [IP, PR, AI, C]

Sample issue: Farmed salmon can be genetically modified to reach market size in half the time of normal fish, and cost half as much to feed. However, entire populations of wild fish could be endangered by mating with bioengineered fish that are released into the wild, with disastrous consequences for the ecosystem.

Sample questions: What are the risks of growing genetically modified crops near fields where traditional crops are growing? Why have some countries banned genetically modified food crops? What impact has the introduction of herbicide-tolerant plants had on local environments? In what ways can insect-resistant plants both improve agriculture and hurt biodiversity? What are some of the possible effects on the environment of releasing bioengineered insects into the wild?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to genetics, including, but not limited to: *spindle, haploid, diploid, heterozygous, homozygous, hemophilia, gamete, ultraviolet radiation, carcinogen, cancer, trisomy, somatic cell,* and *zygote* [C]

D2.2 investigate the process of meiosis, using a microscope or computer simulation, and identify, and draw biological diagrams of, the phases of meiosis [PR, C]

D2.3 solve basic problems in genetics that involve monohybrid crosses, using the Punnett square method [AI, C]

D2.4 compile and analyse qualitative and quantitative data, through laboratory inquiry or computer simulation, on monohybrid crosses, and communicate the results (e.g., record data obtained while performing a "virtual fly" lab, and analyse the results to create a karyotype chart) [PR, AI, C]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the process of meiosis in terms of cell division and the movement of chromosomes

D3.2 explain how the concepts of DNA, genes, chromosomes, alleles, mitosis, and meiosis account for the transmission of hereditary characteristics from generation to generation

D3.3 explain the concepts of genotype, phenotype, dominance, recessiveness, and sex linkage

D3.4 describe some genetic disorders that are caused by chromosomal abnormalities (e.g., non-disjunction) or other genetic mutations

D3.5 describe reproductive technologies such as cloning, artificial insemination, and in vitro fertilization

E. ANATOMY OF MAMMALS

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse the social or economic impact of a technology used to treat systems in the human body, and the impact of lifestyle choices on human health;

E2. investigate, through laboratory inquiry or computer simulation, the anatomy, physiology, and response mechanisms of mammals;

E3. demonstrate an understanding of the structure, function, and interactions of the circulatory, digestive, and respiratory systems of mammals.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse the social or economic impact of a medical device or technology related to the treatment of the human circulatory, respiratory, or digestive system (e.g., a pacemaker, a heart-lung bypass machine, kidney dialysis) [AI, C]

Sample issue: A reliable blood substitute for use during emergencies or blood shortages could save many lives and create huge revenues for its producers. However, clinical trials have shown that patients receiving artificial blood have a significantly higher risk of heart attack than those receiving donated blood, thus increasing medical costs.

Sample questions: Are the costs of the disposable capsules used for capsule endoscopy worth the benefits of detecting gastrointestinal diseases? Why or why not? What social and economic issues arise from the use of respirators to keep gravely injured or terminally ill patients alive?

E1.2 analyse the impact of various lifestyle choices on human health and body systems (e.g., the impact of excessive alcohol consumption on the liver; of smoking on the respiratory system; of loud noise on the auditory system)

Sample issue: The importance of a sensible diet and regular exercise in maintaining healthy body weight is well known. Yet the popularity of fast food and computer games means that many young people are eating too much fat and are not getting enough physical activity. Consequently, childhood obesity levels are on the rise in Canada.

Sample questions: Does information in the media have an impact on your personal lifestyle choices? Why or why not? Why is it important to limit strenuous outdoor activity on smog days or during heat alerts? What are the dangers of eating undercooked hamburgers?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to animal anatomy, including, but not limited to: *systolic contraction, diastolic pressure, diffusion gradient, inhalation, exhalation, coronary, cardiac, ulcer, asthma,* and *constipation* [C]

E2.2 use medical equipment (e.g., a stethoscope, a sphygmomanometer) to monitor a human system, and interpret the data collected [PR, AI]

E2.3 plan and conduct an inquiry to determine the effects of specific variables on the human body (e.g., the effects of exercise and rest on heart rates) [IP, PR, AI]

E2.4 perform a laboratory or computer-simulated dissection of a mammal to identify organs, and explain the relationships between the structures and functions of body systems [PR, AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe the anatomy and physiology of the circulatory system (including the atrium, ventricles, valves, aorta, pulmonary artery, vena cava, capillaries, veins, arteries, blood cells, and platelets), the mechanisms of blood pressure, and the function of the spleen

E3.2 describe the anatomy and physiology of the respiratory system (including the nasal cavity, trachea, larynx, bronchi, bronchioles, alveoli, and oxygenated and deoxygenated blood) and the mechanisms of gas exchange and respiration

E3.3 describe the anatomy and physiology of the digestive system (including the mouth, epiglottis, esophagus, stomach, intestines, liver, and pancreas), the mechanisms of peristalsis, absorption, and mechanical and chemical digestion, and the function of the kidneys

E3.4 explain some of the mechanisms of interaction between a mammal's different body systems (e.g., the exchange of oxygen and carbon dioxide between the respiratory and circulatory systems)

F. PLANTS IN THE NATURAL ENVIRONMENT

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse the roles of plants in ecosystems, and assess the impact of human activities on the balance of plants within those ecosystems;

F2. investigate some of the factors that affect plant growth;

F3. demonstrate an understanding of the structure and physiology of plants and their role in the natural environment.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 analyse, on the basis of research, and report on ways in which plants can be used to sustain ecosystems [IP, PR, AI, C]

Sample issue: Urban areas place intense pressure on ecosystems. Some of the negative impact can be reduced by cultivating urban forests. These green spaces filter air, water, and sunlight; reduce the "urban heat island" effect; provide habitat for wildlife; and increase biodiversity. However, many cities do not set aside enough land for green spaces because of pressures for urban development.

Sample questions: What are some of the environmental and economic benefits of building urban green spaces on large commercial buildings? What role do native plant species in marshes play in filtering organic waste? How have traditional Aboriginal seed maintenance and distribution practices helped sustain ecosystems in Aboriginal communities?

F1.2 assess the positive and negative impact of human activities on the natural balance of plants (e.g., crop rotation, the use of fertilizers and herbicides, the introduction of new species) [AI, C]

Sample issue: The greening of cities with a variety of native plant species helps to maintain biodiversity, restore natural landscapes, and provide food and habitat for local wildlife. However, many urban gardeners introduce non-native plants, which can compete with the native species and may not be hospitable to the local wildlife.

Sample questions: How has increased knowledge about plant growth been applied to improve the resistance of some plants to pests, and allowed those plants to be used in non-native areas? What are the positive and negative effects of such applications? In what ways does monoculture affect the natural balance of plants and the ecosystems they help sustain?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to plants in the environment, including, but not limited to: *xylem, phloem, chloroplast, pistil, stamen, nitrogen fixation,* and *tropism* [C]

F2.2 investigate various techniques of plant propagation (e.g., leaf cutting, stem cutting, root cutting, seed germination, traditional Aboriginal practices) [PR]

F2.3 investigate how chemical compounds (e.g., fertilizers, herbicides, pesticides) and physical factors (e.g., amount of sun and water, quality of soil, pH of soil) affect plant growth [PR, AI]

F2.4 investigate plant tropism by growing and observing plants in a variety of natural and human-made environments [PR]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 describe the structure and physiology of the specialized plant tissues involved in conduction, support, storage, and photosynthesis

F3.2 explain the chemical changes and energy transformations associated with the process of photosynthesis, and compare the reactants (i.e., carbon dioxide, radiant energy, water) to the products (i.e., glucose, oxygen)

F3.3 compare the various means of sexual reproduction (e.g., pollination) and asexual reproduction (e.g., grafting, vegetative propagation, cloning) in plants

F3.4 explain the various roles of plants in the sustainability of the natural environment (e.g., in nutrient cycles, in the water cycle, in erosion control, in wildlife habitats)

F3.5 explain the relationship between the structure of a plant and its external environment, and describe the adaptive attributes that result in natural variation in plant structure (e.g., environmental variables cause variation in leaves within a single plant; in the Arctic, the wild crocus grows close to the ground and is covered with fine hairs)

F3.6 explain the role of plant tropism (e.g., response to stimuli such as light, gravity, and humidity) in a plant's survival

Biology, Grade 12

University Preparation SBI4U

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

Prerequisite: Biology, Grade 11, University Preparation

Big Ideas

Biochemistry

- Technological applications that affect biological processes and cellular functions are used in the food, pharmaceutical, and medical industries.
- Biological molecules and their chemical properties affect cellular processes and biochemical reactions.
- Biochemical compounds play important structural and functional roles in cells of all living organisms.

Metabolic Processes

- All metabolic processes involve chemical changes and energy conversions.
- An understanding of metabolic processes enables people to make informed choices with respect to a range of personal, societal, and environmental issues.

Molecular Genetics

- DNA contains all the genetic information for any living organism.
- Proteins control a wide variety of cellular processes.
- Genetic research and biotechnology have social, legal, and ethical implications.

Homeostasis

- Organisms have strict limits on the internal conditions that they can tolerate.
- Systems that maintain homeostasis rely on feedback mechanisms.
- Environmental factors can affect homeostasis.

Population Dynamics

- Population growth follows predictable patterns.
- The increased consumption of resources and production of waste associated with population growth result in specific stresses that affect Earth’s sustainability.
- Technological developments can contribute to or help offset the ecological footprint associated with population growth and the consumption of natural resources.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Biochemistry	Metabolic Processes	Molecular Genetics	Homeostasis	Population Dynamics
Matter	✓	✓			
Energy	✓	✓			
Systems and Interactions				✓	
Structure and Function	✓	✓	✓	✓	
Sustainability and Stewardship					✓
Change and Continuity			✓	✓	✓

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., dialysis tubing, glassware, sphygmomanometer) and materials (e.g., DNA models, plants, plant cuttings, molecular models), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory and biological materials (e.g., plants and invertebrates); and by using appropriate personal protection

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation (e.g., biological diagrams, three-dimensional molecular models), and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., scientific journalist, fisheries and wildlife officer, physician, infectious disease researcher, geneticist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Evelyn Roden Nelson, Maude Menten, Albert Juan Aguayo, Kimberley J. Fernie, Michael Archer), to the fields under study

B. BIOCHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse technological applications of enzymes in some industrial processes, and evaluate technological advances in the field of cellular biology;

B2. investigate the chemical structures, functions, and chemical properties of biological molecules involved in some common cellular processes and biochemical reactions;

B3. demonstrate an understanding of the structures and functions of biological molecules, and the biochemical reactions required to maintain normal cellular function.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse technological applications related to enzyme activity in the food and pharmaceutical industries (e.g., the production of dairy products; breadmaking; the use of enzymes to control reaction rates in pharmaceuticals) [AI, C]

Sample issue: Natural enzymes are used in many food production processes to speed up chemical reactions, which reduces water usage and energy consumption. Scientists are now designing and producing synthetic enzymes that will be more efficient catalysts and allow new technological applications in medicine and industry.

Sample questions: Why are there so many different varieties of cheese when the production process is basically the same for all cheeses? What types of food production processes use enzymes to improve production yields? How do they do so? How and why are enzymes used as pharmaceutical supplements to treat digestive system disorders such as celiac disease and lactose intolerance?

B1.2 evaluate, on the basis of research, some advances in cellular biology and related technological applications (e.g., new treatments for cancer, HIV/AIDS, and hepatitis C; radioisotopic labelling to study the function of internal organs; fluorescence to study genetic material within cells; forensic biological techniques to aid in crime resolution) [IP, PR, AI, C]

Sample issue: In nuclear medicine, radioactive compounds are injected into the body so that images of cells can be scanned to diagnose and treat medical conditions such as cancer and heart disease. Radioisotopes may now be used so routinely and effectively that we have come to rely on them despite concerns about production safety.

Sample questions: How are drugs used to target tumour cells during chemotherapy? How are scientists using bacteria to create antibiotics that fight drug-resistant bacteria strains? What role might nanotechnologies play in replacing current diagnostic and treatment technologies?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to biochemistry, including, but not limited to: *active and passive transport*, *covalent and ionic bond*, *allosteric site*, *substrate*, *substrate-enzyme complex*, and *inhibition* [C]

B2.2 plan and conduct an investigation to demonstrate the movement of substances across a membrane (e.g., the effects of salt water and distilled water on a potato) [IP, PR]

B2.3 construct and draw three-dimensional molecular models of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids [PR, C]

B2.4 conduct biological tests to identify biochemical compounds found in various food samples (e.g., use Benedict's solution to test for carbohydrates in food samples), and compare the biochemical compounds found in each food to those found in the others [PR, AI, C]

B2.5 plan and conduct an investigation related to a cellular process (e.g., factors that affect enzyme activity; factors that affect transport of substances across cell membranes), using appropriate laboratory equipment and techniques, and report the results in an appropriate format [IP, PR, C]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 explain the roles of various organelles, such as lysosomes, vacuoles, mitochondria, internal cell membranes, ribosomes, smooth and rough endoplasmic reticulum, and Golgi bodies, in cellular processes

B3.2 describe the structure of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids, and explain their function within cells

B3.3 identify common functional groups within biological molecules (e.g., hydroxyl, carbonyl, carboxyl, amino, phosphate), and explain how they contribute to the function of each molecule

B3.4 describe the chemical structures and mechanisms of various enzymes

B3.5 identify and describe the four main types of biochemical reactions (oxidation-reduction [redox], hydrolysis, condensation, and neutralization)

B3.6 describe the structure of cell membranes according to the fluid mosaic model, and explain the dynamics of passive transport, facilitated diffusion, and the movement of large particles across the cell membrane by the processes of endocytosis and exocytosis

C. METABOLIC PROCESSES

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse the role of metabolic processes in the functioning of biotic and abiotic systems, and evaluate the importance of an understanding of these processes and related technologies to personal choices made in everyday life;

C2. investigate the products of metabolic processes such as cellular respiration and photosynthesis;

C3. demonstrate an understanding of the chemical changes and energy conversions that occur in metabolic processes.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse the role of metabolic processes in the functioning of and interactions between biotic and abiotic systems (e.g., specialized microbes and enzymes in biotechnological applications to treat wastewater in the pulp and paper industry; microbes and enzymes in bioremediation, such as in the cleanup of oil spills; energy transfer from producers to consumers) [AI, C]

Sample issue: Most restaurants dispose of cooking oil and grease in an environmentally sound way to avoid contaminating municipal sewer systems. One method they can use is bioaugmentation, which uses microorganisms to metabolize oils into bacterial biomass, carbon dioxide, and water. However, this process can create unpleasant odours, which are undesirable in a food service setting.

Sample questions: How do symbiotic bacteria use metabolic processes to produce biohydrogen from food waste? How are microbes used in the bioremediation of contaminated groundwater sites? What is the relationship between the position of a particular species in the food chain and the energy required to maintain that species?

C1.2 assess the relevance, to their personal lives and to the community, of an understanding of cell biology and related technologies (e.g., knowledge of metabolic processes is relevant to personal choices about exercise, diet, and the use of pharmacological substances; knowledge of cellular processes aids in our understanding and treatment of mitochondrial diseases [a group of neuromuscular diseases]) [AI, C]

Sample issue: Some fad weight-loss diets include pills that are believed to speed up the body's metabolism to help a person lose weight quickly. Other diets rely on very low calorie intake for rapid weight loss. However, such methods can lead to destructive metabolic processes in the body, causing organ failure.

Sample questions: How does stem-cell research related to degenerative diseases use technologies to change the metabolic processes of the cells? Why is it important when changing your diet to know how the cells in your body will react to the introduction of new substances or the removal of other substances?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to metabolism, including, but not limited to: *energy carriers, glycolysis, Krebs cycle, electron transport chain, ATP synthase, oxidative phosphorylation, chemiosmosis, proton pump, photolysis, Calvin cycle, light and dark reactions,* and *cyclic and noncyclic phosphorylation* [C]

C2.2 conduct a laboratory investigation into the process of cellular respiration to identify the products of the process, interpret the qualitative observations, and display them in an appropriate format [PR, AI, C]

C2.3 conduct a laboratory investigation of the process of photosynthesis to identify the products of the process, interpret the qualitative observations, and display them in an appropriate format [PR, AI, C]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 explain the chemical changes and energy conversions associated with the processes of aerobic and anaerobic cellular respiration (e.g., in aerobic cellular respiration, glucose and oxygen react to produce carbon dioxide, water, and energy in the form of heat and ATP; in anaerobic cellular respiration, yeast reacts with glucose in the absence of oxygen to produce carbon dioxide and ethanol)

C3.2 explain the chemical changes and energy conversions associated with the process of photosynthesis (e.g., carbon dioxide and water react with sunlight to produce oxygen and glucose)

C3.3 use the laws of thermodynamics to explain energy transfer in the cell during the processes of cellular respiration and photosynthesis

C3.4 describe, compare, and illustrate (e.g., using flow charts) the matter and energy transformations that occur during the processes of cellular respiration (aerobic and anaerobic) and photosynthesis, including the roles of oxygen and organelles such as mitochondria and chloroplasts

D. MOLECULAR GENETICS

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse some of the social, ethical, and legal issues associated with genetic research and biotechnology;

D2. investigate, through laboratory activities, the structures of cell components and their roles in processes that occur within the cell;

D3. demonstrate an understanding of concepts related to molecular genetics, and how genetic modification is applied in industry and agriculture.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse, on the basis of research, some of the social, ethical, and legal implications of biotechnology (e.g., the bioengineering of animal species, especially those intended for human consumption; the cultivation of transgenic crops; the patenting of life forms; cloning) [IP, PR, AI, C]

Sample issue: Corporations that have patented genetically modified (GM) seeds legally require farmers to buy new seeds from them each planting season. Corporations that find GM crops on a farm that did not purchase their seed can take the farmer to court. However, natural processes such as cross-pollination can result in the migration of GM crops to neighbouring farms.

Sample questions: Should private companies be able to patent life forms, including genetic material? Why or why not? Who owns and controls our personal genetic information? Who should have access to our personal genetic information and decide how it will be used? What are the ethical implications of reproductive technologies that allow postmenopausal women to conceive?

D1.2 analyse, on the basis of research, some key aspects of Canadian regulations pertaining to biotechnology (e.g., current or potential legislation for mandatory DNA fingerprinting, human cloning, ownership of a genome, patenting of genetically modified organisms), and compare them to regulations from another jurisdiction [IP, PR, AI, C]

Sample issue: Modern biotechnologies, such as selective breeding, are regulated under Health Canada's Food and Drugs Act and the Canadian Environmental Protection Act. It is an ongoing challenge to ensure that our regulations keep up with advances in scientific knowledge and technologies, as well as with developments in other countries.

Sample questions: What is the role of the Canadian Food Inspection Agency with respect to biotechnology? What role does the Canadian Environmental Protection Act play in regulating biotechnology? Why was bovine growth hormone approved for use in dairy cattle in the United States but not in Canada? Why does Mexico have laws to limit the cultivation of genetically modified corn? What countries have banned human cloning? What is Canada's position on this issue?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to molecular genetics, including, but not limited to: *polymerase I, II, and III, DNA ligase, helicase, Okazaki fragment, mRNA, rRNA, tRNA, codon, anticodon, translation, transcription,* and *ribosome subunits* [C]

D2.2 analyse a simulated strand of DNA to determine the genetic code and base pairing of DNA (e.g., determine base sequences of DNA for a protein; analyse base sequences in DNA to recognize an anomaly) [AI]

D2.3 conduct an investigation to extract DNA from a specimen of plant or animal protein [PR]

D2.4 investigate and analyse the cell components involved in the process of protein synthesis, using appropriate laboratory equipment and techniques, or a computer simulation [PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the current model of DNA replication, and describe the different repair mechanisms that can correct mistakes in DNA sequencing

D3.2 compare the structures and functions of RNA and DNA, and explain their roles in the process of protein synthesis

D3.3 explain the steps involved in the process of protein synthesis and how genetic expression is controlled in prokaryotes and eukaryotes by regulatory proteins (e.g., the role of operons in prokaryotic cells; the mechanism of gene expression in eukaryotic cells)

D3.4 explain how mutagens, such as radiation and chemicals, can cause mutations by changing the genetic material in cells (e.g., the mechanisms and effects of point mutations and frameshift mutations)

D3.5 describe some examples of genetic modification, and explain how it is applied in industry and agriculture (e.g., the processes involved in cloning, or in the sequencing of DNA bases; the processes involved in the manipulation of genetic material and protein synthesis; the development and mechanisms of the polymerization chain reaction)

D3.6 describe the functions of some of the cell components used in biotechnology (e.g., the roles of plasmids, restriction enzymes, recombinant DNA, and vectors in genetic engineering)

D3.7 describe, on the basis of research, some of the historical scientific contributions that have advanced our understanding of molecular genetics (e.g., discoveries made by Frederick Griffith, Watson and Crick, Hershey and Chase)

E. HOMEOSTASIS

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. evaluate the impact on the human body of selected chemical substances and of environmental factors related to human activity;

E2. investigate the feedback mechanisms that maintain homeostasis in living organisms;

E3. demonstrate an understanding of the anatomy and physiology of human body systems, and explain the mechanisms that enable the body to maintain homeostasis.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 assess, on the basis of findings from a case study, the effects on the human body of taking chemical substances to enhance performance or improve health (e.g., the risks and benefits of taking large quantities of vitamins or amino acids; the effects on the human body of substances that people use to cope with stress) [PR, AI, C]

Sample issue: Steroids are a class of drugs that can be used for healing and building of tissues under proper medical supervision. However, if used for the wrong purpose, such as athletic performance enhancement, or if they are taken incorrectly, steroids can be dangerous and result in negative long-term effects on many body systems.

Sample questions: How do certain classes of drugs help with neurotransmission in the brain? What effects does aloe vera have on the human body? How do common antidepressants work? Why should people, especially young people, be carefully monitored when on such medications? What are the possible side effects of statin drugs used to lower cholesterol? Why has the federal government proposed legislation to regulate natural health products?

E1.2 evaluate, on the basis of research, some of the human health issues that arise from the impact of human activities on the environment (e.g., the effects of synthetic estrogen compounds released into our water systems; the effects of leaching of compounds from plastic products into soil and water) [IP, PR, AI, C]

Sample issue: Human-produced biosolids are a low-cost source of nutrient-rich organic matter that is often spread on agricultural land rather than being sent for incineration or landfill disposal. Opponents of land application of biosolids are concerned about the potential health impact of heavy metals, bacteria, and drugs that may remain in the biosolids.

Sample questions: In what ways have mining, forestry, and hydroelectric developments affected the health of Aboriginal people in Northern Ontario? What are the links between air pollution and respiratory diseases such as asthma? What types of human activity have led to the thinning of the ozone? What human health conditions are related to this phenomenon? How can the dumping of chemicals down sinks and into storm sewers affect the incidence of skin conditions among swimmers at local beaches?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to homeostasis, including, but not limited to: *insulin, testosterone, estrogen, nephron, dialysis, pituitary, synapse,* and *acetylcholine* [C]

E2.2 plan and construct a model to illustrate the essential components of the homeostatic process (e.g., create a flow chart that illustrates representative feedback mechanisms in living things) [IP, AI, C]

E2.3 plan and conduct an investigation to study a feedback system (e.g., stimulus response loop) [IP, PR, AI]

E2.4 plan and conduct an investigation to study the response mechanism of an invertebrate to external stimuli (e.g., the instinctive behaviour of an invertebrate in response to a stimulus such as light), using appropriate laboratory equipment and techniques [IP, PR, AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe the anatomy and physiology of the endocrine, excretory, and nervous systems, and explain how these systems interact to maintain homeostasis

E3.2 explain how reproductive hormones act in human feedback mechanisms to maintain homeostasis (e.g., the actions of male and female reproductive hormones on their respective body systems)

E3.3 describe the homeostatic processes involved in maintaining water, ionic, thermal, and acid–base equilibrium, and explain how these processes help body systems respond to both a change in environment and the effects of medical treatments (e.g., the role of feedback mechanisms in water balance or thermoregulation; how the buffering system of blood maintains the body's pH balance; the effect of medical treatments on the endocrine system; the effects of chemotherapy on homeostasis)

F. POPULATION DYNAMICS

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse the relationships between population growth, personal consumption, technological development, and our ecological footprint, and assess the effectiveness of some Canadian initiatives intended to assist expanding populations;

F2. investigate the characteristics of population growth, and use models to calculate the growth of populations within an ecosystem;

F3. demonstrate an understanding of concepts related to population growth, and explain the factors that affect the growth of various populations of species.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 analyse the effects of human population growth, personal consumption, and technological development on our ecological footprint (e.g., the deforestation resulting from expanding development and demand for wood products causes the destruction of habitats that support biological diversity; the acidification of lakes associated with some industrial processes causes a decrease in fish populations) [AI, C]

Sample issue: Every day, millions of Canadians drive their vehicles to work, school, or entertainment venues, which creates greenhouse gases and consumes non-renewable resources. These behaviours, and many other consumption habits, all contribute to our ecological footprint. Many experts believe that we are consuming more resources each year than Earth can produce.

Sample questions: How does the Living Planet Index (LPI) help a nation to assess its ecological footprint and sustain its population? How does the planned obsolescence of electronic devices and appliances contribute to our ecological footprint? What impact has rapid population growth into the suburbs had on the local environment? What is the environmental impact of using packaged infant formula instead of breastfeeding a baby for the first six months of life?

F1.2 assess, on the basis of research, the effectiveness of some Canadian technologies and projects intended to nourish expanding populations (e.g., the risks and benefits of growing genetically modified canola; some of the sustainable development projects funded by the Canadian International Development Agency [CIDA]) [IP, PR, AI, C]

Sample issue: Every year, millions of children in developing nations die from diseases and malnutrition related to micronutrient deficiencies. The Canada-based Micronutrient Initiative develops, implements, and monitors programs aimed at eliminating vitamin and mineral deficiencies in expanding populations. The main challenge of such an initiative is to create sustainable solutions that will reach all those who need help.

Sample questions: How are Canadian programs helping to reverse the effects of land degradation and promote sustainable farming in semi-arid and dry sub-humid areas? What is Canada's role in the Flour Fortification Initiative, and how effectively does this initiative meet its goal of nourishing expanding populations?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to population dynamics, including, but not limited to: *carrying capacity*, *population growth*, *population cycle*, *fecundity*, and *mortality* [C]

F2.2 use conceptual and mathematical population growth models to calculate the growth of populations of various species in an ecosystem (e.g., use the concepts of exponential, sigmoid, and sinusoidal growth to estimate the sizes of various populations) [PR, AI, C]

F2.3 determine, through laboratory inquiry or using computer simulations, the characteristics of population growth of two different populations (e.g., the different population cycles of a predator and its prey; the population cycles of two populations that compete for food; the increase of Aboriginal compared to non-Aboriginal populations and the significant difference in average age between the two groups) [PR, AI, C]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 explain the concepts of interaction (e.g., competition, predation, defence mechanism, symbiotic relationship, parasitic relationship) between different species

F3.2 describe the characteristics of a given population, such as its growth, density (e.g., fecundity, mortality), distribution, and minimum viable size

F3.3 explain factors such as carrying capacity, fecundity, density, and predation that cause fluctuation in populations, and analyse the fluctuation in the population of a species of plant, wild animal, or microorganism

F3.4 explain the concept of energy transfer in a human population in terms of the flow of food energy in the production, distribution, and use of food resources

F3.5 explain how a change in one population in an aquatic or terrestrial ecosystem can affect the entire hierarchy of living things in that system (e.g., how the disappearance of crayfish from a lake causes a decrease in the bass population of the lake; how the disappearance of beaver from an ecosystem causes a decrease in the wolf population in that ecosystem)

CHEMISTRY

Chemistry, Grade 11

University Preparation SCH3U

This course enables students to deepen their understanding of chemistry through the study of the properties of chemicals and chemical bonds; chemical reactions and quantitative relationships in those reactions; solutions and solubility; and atmospheric chemistry and the behaviour of gases. Students will further develop their analytical skills and investigate the qualitative and quantitative properties of matter, as well as the impact of some common chemical reactions on society and the environment.

Prerequisite: Science, Grade 10, Academic

Big Ideas

Matter, Chemical Trends, and Chemical Bonding

- Every element has predictable chemical and physical properties determined by its structure.
- The type of chemical bond in a compound determines the physical and chemical properties of that compound.
- It is important to use chemicals properly to minimize the risks to human health and the environment.

Chemical Reactions

- Chemicals react in predictable ways.
- Chemical reactions and their applications have significant implications for society and the environment.

Quantities in Chemical Reactions

- Relationships in chemical reactions can be described quantitatively.
- The efficiency of chemical reactions can be determined and optimized by applying an understanding of quantitative relationships in such reactions.

Solutions and Solubility

- Properties of solutions can be described qualitatively and quantitatively, and can be predicted.
- Living things depend for their survival on the unique physical and chemical properties of water.
- People have a responsibility to protect the integrity of Earth's water resources.

Gases and Atmospheric Chemistry

- Properties of gases can be described qualitatively and quantitatively, and can be predicted.
- Air quality can be affected by human activities and technology.
- People have a responsibility to protect the integrity of Earth's atmosphere.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Matter, Chemical Trends, and Chemical Bonding	Chemical Reactions	Quantities in Chemical Reactions	Solutions and Solubility	Gases and Atmospheric Chemistry
Matter	✓	✓	✓	✓	✓
Energy		✓	✓	✓	✓
Systems and Interactions		✓	✓		
Structure and Function	✓			✓	✓
Sustainability and Stewardship	✓	✓		✓	✓
Change and Continuity	✓	✓			

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., a balance, glassware, titration instruments) and materials (e.g., molecular model kits, solutions), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection (e.g., wearing safety goggles)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., pharmacist, forensic scientist, chemical engineer, food scientist, environmental chemist, occupational health and safety officer, water quality analyst, atmospheric scientist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Carol Ann Budd, Edgar Steacie, Raymond Lemieux, Louis Taillefer, F. Kenneth Hare), to the fields under study

B. MATTER, CHEMICAL TRENDS, AND CHEMICAL BONDING

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse the properties of commonly used chemical substances and their effects on human health and the environment, and propose ways to lessen their impact;

B2. investigate physical and chemical properties of elements and compounds, and use various methods to visually represent them;

B3. demonstrate an understanding of periodic trends in the periodic table and how elements combine to form chemical bonds.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse, on the basis of research, the properties of a commonly used but potentially harmful chemical substance (e.g., fertilizer, pesticide, a household cleaning product, materials used in electronics and batteries) and how that substance affects the environment, and propose ways to lessen the harmfulness of the substance (e.g., by reducing the amount used, by modifying one of its chemical components) or identify alternative substances that could be used for the same purpose [IP, PR, AI, C]

Sample issue: Many commercial household cleaning products contain corrosive substances that can accumulate in the environment. There are now many "green" cleaners that do not contain these substances, although some of these products may not be as environmentally friendly as claimed.

Sample questions: Why is it more environmentally friendly to use latex rather than oil-based paint? Why should paint never be poured down a drain? What properties of some common pharmaceuticals allow them to stay in water systems and influence the growth and development of organisms? What are some ways in which this impact can be reduced?

B1.2 evaluate the risks and benefits to human health of some commonly used chemical substances (e.g., chemical additives in foods; pharmaceuticals; cosmetics and perfumes; household cleaning products) [AI, C]

Sample issue: Artificial sweeteners, such as aspartame, are used as sugar substitutes to reduce calories in processed foods and beverages. Although such sweeteners may benefit people who are watching their weight, or those with diabetes, some experts say that their harmful effects on human health may outweigh their benefits.

Sample questions: How can the use of non-stick cookware help reduce the amount of fat in our diet? What risks are associated with the use of such cookware? What are the risks and benefits of using sunscreens that contain PABA? What are the risks and benefits of using insect repellents that contain DEET?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to chemical trends and chemical bonding, including, but not limited to: *atomic radius, effective nuclear charge, electronegativity, ionization energy,* and *electron affinity* [C]

B2.2 analyse data related to the properties of elements within a period (e.g., ionization energy, atomic radius) to identify general trends in the periodic table [AI]

B2.3 use an inquiry process to investigate the chemical reactions of elements (e.g., metals, non-metals) with other substances (e.g., oxygen, acids, water), and produce an activity series using the resulting data [PR, AI]

B2.4 draw Lewis structures to represent the bonds in ionic and molecular compounds [PR, C]

B2.5 predict the nature of a bond (e.g., non-polar covalent, polar covalent, ionic), using electronegativity values of atoms [AI]

B2.6 build molecular models, and write structural formulae, for molecular compounds containing single and multiple bonds (e.g., CO_2, H_2O, C_2H_4), and for ionic crystalline structures (e.g., NaCl) [PR, AI, C]

B2.7 write chemical formulae of binary and polyatomic compounds, including those with multiple valences, and name the compounds using the International Union of Pure and Applied Chemistry (IUPAC) nomenclature system [AI, C]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 explain the relationship between the atomic number and the mass number of an element, and the difference between isotopes and radioisotopes of an element

B3.2 explain the relationship between isotopic abundance of an element's isotopes and the relative atomic mass of the element

B3.3 state the periodic law, and explain how patterns in the electron arrangement and forces in atoms result in periodic trends (e.g., in atomic radius, ionization energy, electron affinity, electronegativity) in the periodic table

B3.4 explain the differences between the formation of ionic bonds and the formation of covalent bonds

B3.5 compare and contrast the physical properties of ionic and molecular compounds (e.g., NaCl and CH_4; NaOH and H_2O)

C. CHEMICAL REACTIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse chemical reactions used in a variety of applications, and assess their impact on society and the environment;

C2. investigate different types of chemical reactions;

C3. demonstrate an understanding of the different types of chemical reactions.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse, on the basis of research, chemical reactions used in various industrial processes (e.g., pulp and paper production, mining, chemical manufacturing) that can have an impact on the health and safety of local populations [IP, PR, AI, C]

Sample issue: Base metal smelting produces useful metals such as zinc, lead, copper, and nickel directly from their ores. However, during smelting, harmful compounds can be released into the environment, including cadmium, arsenic, sulfur dioxide, and mercury, all of which can endanger the health and safety of local populations.

Sample questions: What are some chemical reactions used in the manufacture of paper? How might the reactants or products of the pulp and paper production process affect the health of people living near the plant? In what ways might the leaching of chemicals from tailing ponds affect the water quality in a local community? In what ways do toxic chemical fires affect local communities?

C1.2 assess the effectiveness of some applications of chemical reactions that are used to address social and environmental needs and problems [AI, C]

Sample issue: Scrubber systems are a group of air pollution control devices used by industry to remove or neutralize acid exhaust gases before they reach the atmosphere. Scrubber technologies help to reduce acid precipitation, but there are many different scrubbing techniques with varying levels of effectiveness in controlling acid gas emissions.

Sample questions: How are chemical reactions used to remediate environments affected by chemical spills? How can tailing ponds be rehabilitated to lessen the effects of hazardous chemicals on plant populations? What types of chemical reactions can change a toxic chemical into one that is less toxic or non-toxic?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to chemical reactions, including, but not limited to: *neutralization*, *precipitate*, *acidic*, and *basic* [C]

C2.2 write balanced chemical equations to represent synthesis, decomposition, single displacement, double displacement, and combustion reactions, using the IUPAC nomenclature system [PR, AI, C]

C2.3 investigate synthesis, decomposition, single displacement, and double displacement reactions, by testing the products of each reaction (e.g., test for products such as gases, the presence of an acid, or the presence of a base) [PR, AI]

C2.4 predict the products of different types of synthesis and decomposition reactions (e.g., synthesis reactions in which simple compounds are formed; synthesis reactions of metallic or non-metallic oxides with water; decomposition reactions, in which a chemical compound is separated into several compounds) [AI]

C2.5 predict the products of single displacement reactions, using the metal activity series and the halogen series [AI]

C2.6 predict the products of double displacement reactions (e.g., the formation of precipitates or gases; neutralization) [AI]

C2.7 design an inquiry to demonstrate the difference between a complete and an incomplete combustion reaction [IP, C]

C2.8 plan and conduct an inquiry to compare the properties of non-metal oxide solutions and metal oxide solutions (e.g., carbon dioxide reacts with water to make water acidic; magnesium oxide reacts with water to make water basic) [IP, PR, AI]

C2.9 investigate neutralization reactions (e.g., neutralize a dilute solution of sodium hydroxide with a dilute solution of hydrochloric acid, and isolate the sodium chloride produced) [PR]

C2.10 plan and conduct an inquiry to demonstrate a single displacement reaction, using elements from the metal activity series [IP, PR]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 identify various types of chemical reactions, including synthesis, decomposition, single displacement, double displacement, and combustion

C3.2 explain the difference between a complete combustion reaction and an incomplete combustion reaction (e.g., complete and incomplete combustion of hydrocarbon fuels)

C3.3 explain the chemical reactions that result in the formation of acids and bases from metal oxides and non-metal oxides (e.g., calcium oxide reacts with water to produce a basic solution; carbon dioxide reacts with water to produce an acidic solution)

D. QUANTITIES IN CHEMICAL REACTIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse processes in the home, the workplace, and the environmental sector that use chemical quantities and calculations, and assess the importance of quantitative accuracy in industrial chemical processes;

D2. investigate quantitative relationships in chemical reactions, and solve related problems;

D3. demonstrate an understanding of the mole concept and its significance to the quantitative analysis of chemical reactions.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse processes in the home, the workplace, and the environmental sector that involve the use of chemical quantities and calculations (e.g., mixing household cleaning solutions, calculating chemotherapy doses, monitoring pollen counts) [AI, C]

Sample issue: Health care professionals are expected to calculate dosages of prescription drugs accurately and safely. This requires precision in applying fractions, decimals, ratios, percentages, and metric conversions. Despite the care taken by health care professionals, improper medication use by patients accounts for about 30% of hospital emergency department visits.

Sample questions: Why is baking powder used in cake batter? What happens when too much or too little of that ingredient is used? Why might two people on the same drug regimen not necessarily take the same dosage to treat the same illness? How are carbon dioxide emissions calculated and why are they monitored?

D1.2 assess, on the basis of research, the importance of quantitative accuracy in industrial chemical processes and the potential impact on the environment if quantitative accuracy is not observed [IP, PR, AI, C]

Sample issue: Errors in quantitative accuracy have played a role in many industrial chemical disasters worldwide. Failing to adjust the quantities of chemicals needed to produce different batch sizes of a product have created runaway reactions, resulting in huge explosions. Such industrial accidents can have devastating short- and long-term effects on the environment.

Sample questions: Why is it important to use the correct salt-sand mix on highways during winter storms? Why is it important to correctly measure the chemicals used in water treatment plants? How might incorrect measurements affect the environment? How and why are environmental contaminants monitored in soil, water, and air around a chemical manufacturing plant?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to quantities in chemical reactions, including, but not limited to: *stoichiometry*, *percentage yield*, *limiting reagent*, *mole*, and *atomic mass* [C]

D2.2 conduct an inquiry to calculate the percentage composition of a compound (e.g., a hydrate) [PR, AI]

D2.3 solve problems related to quantities in chemical reactions by performing calculations involving quantities in moles, number of particles, and atomic mass [AI]

D2.4 determine the empirical formulae and molecular formulae of various chemical compounds, given molar masses and percentage composition or mass data [AI]

D2.5 calculate the corresponding mass, or quantity in moles or molecules, for any given reactant or product in a balanced chemical equation as well as for any other reactant or product in the chemical reaction [AI]

D2.6 solve problems related to quantities in chemical reactions by performing calculations involving percentage yield and limiting reagents [AI]

D2.7 conduct an inquiry to determine the actual yield, theoretical yield, and percentage yield of the products of a chemical reaction (e.g., a chemical reaction between steel wool and copper(II) sulfate solution), assess the effectiveness of the procedure, and suggest sources of experimental error [PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the law of definite proportions

D3.2 describe the relationships between Avogadro's number, the mole concept, and the molar mass of any given substance

D3.3 explain the relationship between the empirical formula and the molecular formula of a chemical compound

D3.4 explain the quantitative relationships expressed in a balanced chemical equation, using appropriate units of measure (e.g., moles, grams, atoms, ions, molecules)

E. SOLUTIONS AND SOLUBILITY

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse the origins and effects of water pollution, and a variety of economic, social, and environmental issues related to drinking water;

E2. investigate qualitative and quantitative properties of solutions, and solve related problems;

E3. demonstrate an understanding of qualitative and quantitative properties of solutions.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse the origins and cumulative effects of pollutants that enter our water systems (e.g., landfill leachates, agricultural run-off, industrial effluents, chemical spills), and explain how these pollutants affect water quality [AI, C]

Sample issue: Golf courses use fertilizer and irrigation systems to sustain the vegetation. However, chemical substances, when combined with water, may run off and pollute local water systems.

Sample questions: What pollutants might be found in untreated wastewater from a chicken farm or a poultry-processing plant? How do leachates from old landfill sites enter our water system? How might they affect the water quality of local streams? What are some of the sources and effects of mercury in water systems? What impact might this contaminant have on Aboriginal communities that depend on fishing as a source of food?

E1.2 analyse economic, social, and environmental issues related to the distribution, purification, or use of drinking water (e.g., the impact on the environment of the use of bottled water) [AI, C]

Sample issue: In developing countries, thousands of people, many of them children, die every year from drinking contaminated water. Many of these countries cannot afford to build water treatment plants. In North America, where safe water is generally available, we spend millions of dollars on bottled water, draining sources of fresh water and challenging waste-disposal systems.

Sample questions: What are the economic costs of building, maintaining, and monitoring water-purification plants? What are the social and environmental costs if these plants are not properly maintained and monitored? How effective are municipal wastewater treatment processes at removing pharmaceuticals such as hormones and antibiotics from our drinking water? What public health concerns are associated with the consumption of water bottled in plastic containers?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to aqueous solutions and solubility, including, but not limited to: *concentration, solubility, precipitate, ionization, dissociation, pH, dilute, solute,* and *solvent* [C]

E2.2 solve problems related to the concentration of solutions by performing calculations involving moles, and express the results in various units (e.g., moles per litre, grams per 100 mL, parts per million or parts per billion, mass, volume per cent) [AI, C]

E2.3 prepare solutions of a given concentration by dissolving a solid solute in a solvent or by diluting a concentrated solution [PR]

E2.4 conduct an investigation to analyse qualitative and quantitative properties of solutions (e.g., perform a qualitative analysis of ions in a solution) [PR, AI]

E2.5 write balanced net ionic equations to represent precipitation and neutralization reactions [AI, C]

E2.6 use stoichiometry to solve problems involving solutions and solubility [AI]

E2.7 determine the concentration of an acid or a base in a solution (e.g., the concentration of acetic acid in vinegar), using the acid–base titration technique [PR, AI]

E2.8 conduct an investigation to determine the concentrations of pollutants in their local treated drinking water, and compare the results to commonly used guidelines and standards (e.g., provincial and federal standards) [PR, AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe the properties of water (e.g., polarity, hydrogen bonding), and explain why these properties make water such a good solvent

E3.2 explain the process of formation for solutions that are produced by dissolving ionic and molecular compounds (e.g., salt, oxygen) in water, and for solutions that are produced by dissolving non-polar solutes in non-polar solvents (e.g., grease in vegetable oil)

E3.3 explain the effects of changes in temperature and pressure on the solubility of solids, liquids, and gases (e.g., explain how a change in temperature or atmospheric pressure affects the solubility of oxygen in lake water)

E3.4 identify, using a solubility table, the formation of precipitates in aqueous solutions (e.g., the use of iron or aluminum compounds to precipitate and remove phosphorus from wastewater)

E3.5 explain the Arrhenius theory of acids and bases

E3.6 explain the difference between strong and weak acids, and between strong and weak bases, in terms of degree of ionization

F. GASES AND ATMOSPHERIC CHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse the cumulative effects of human activities and technologies on air quality, and describe some Canadian initiatives to reduce air pollution, including ways to reduce their own carbon footprint;

F2. investigate gas laws that explain the behaviour of gases, and solve related problems;

F3. demonstrate an understanding of the laws that explain the behaviour of gases.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 analyse the effects on air quality of some technologies and human activities (e.g., smelting; driving gas-powered vehicles), including their own activities, and propose actions to reduce their personal carbon footprint [AI, C]

Sample issue: Gas-powered lawnmowers cut grass quickly and efficiently, but they emit greenhouse gases. However, there are several alternatives, including electric or push mowers or replacing lawn with a naturalized garden.

Sample questions: In what ways does our consumption of products imported from distant countries affect our carbon footprint? How might "eat local–buy local" initiatives help to reduce our carbon footprint? How effectively does the use of digital communications for business reduce our carbon footprint?

F1.2 assess air quality conditions for a given Canadian location, using Environment Canada's Air Quality Health Index, and report on some Canadian initiatives to improve air quality and reduce greenhouse gases (e.g., Ontario's Drive Clean program to control vehicle emissions) [AI, C]

Sample issue: Historically, mining and smelting polluted the air, land, and water around Sudbury, Ontario. More recently, as a result of government regulations, industry has significantly reduced emissions, leading to an improvement in air quality and reversal in the acidification of local waterways.

Sample questions: How effective has Ontario's Drive Clean program been in reducing greenhouse gas emissions in the province? What are some industrial and geographic factors that might make air quality in some communities very different from that in others? What are some municipal governments doing to improve local air quality? How can public transit initiatives help improve air quality? What are the limitations of such initiatives?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to gases and atmospheric chemistry, including, but not limited to: *standard temperature*, *standard pressure*, *molar volume*, and *ideal gas* [C]

F2.2 determine, through inquiry, the quantitative and graphical relationships between the pressure, volume, and temperature of a gas [PR, AI]

F2.3 solve quantitative problems by performing calculations based on Boyle's law, Charles's law, Gay-Lussac's law, the combined gas law, Dalton's law of partial pressures, and the ideal gas law [AI]

F2.4 use stoichiometry to solve problems related to chemical reactions involving gases (e.g., problems involving moles, number of atoms, number of molecules, mass, and volume) [AI]

F2.5 determine, through inquiry, the molar volume or molar mass of a gas produced by a chemical reaction (e.g., the molar volume of hydrogen gas from the reaction of magnesium with hydrochloric acid) [PR, AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 identify the major and minor chemical components of Earth's atmosphere

F3.2 describe the different states of matter, and explain their differences in terms of the forces between atoms, molecules, and ions

F3.3 use the kinetic molecular theory to explain the properties and behaviour of gases in terms of types and degrees of molecular motion

F3.4 describe, for an ideal gas, the quantitative relationships that exist between the variables of pressure, volume, temperature, and amount of substance

F3.5 explain Dalton's law of partial pressures, Boyle's law, Charles's law, Gay-Lussac's law, the combined gas law, and the ideal gas law

F3.6 explain Avogadro's hypothesis and how his contribution to the gas laws has increased our understanding of the chemical reactions of gases

Chemistry, Grade 12

University Preparation SCH4U

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

Prerequisite: Chemistry, Grade 11, University Preparation

Big Ideas

Organic Chemistry

- Organic compounds have predictable chemical and physical properties determined by their respective structures.
- Organic chemical reactions and their applications have significant implications for society, human health, and the environment.

Structure and Properties of Matter

- The nature of the attractive forces that exist between particles in a substance determines the properties and limits the uses of that substance.
- Technological devices that are based on the principles of atomic and molecular structures can have societal benefits and costs.

Energy Changes and Rates of Reaction

- Energy changes and rates of chemical reactions can be described quantitatively.
- Efficiency of chemical reactions can be improved by applying optimal conditions.
- Technologies that transform energy can have societal and environmental costs and benefits.

Chemical Systems and Equilibrium

- Chemical systems are dynamic and respond to changing conditions in predictable ways.
- Applications of chemical systems at equilibrium have significant implications for nature and industry.

Electrochemistry

- Oxidation and reduction are paired chemical reactions in which electrons are transferred from one substance to another in a predictable way.
- The control and applications of oxidation and reduction reactions have significant implications for industry, health and safety, and the environment.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Organic Chemistry	Structure and Properties of Matter	Energy Changes and Rates of Reaction	Chemical Systems and Equilibrium	Electrochemistry
Matter	✓	✓	✓	✓	✓
Energy			✓	✓	✓
Systems and Interactions	✓			✓	
Structure and Function	✓	✓			
Sustainability and Stewardship	✓		✓	✓	✓
Change and Continuity			✓	✓	

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., glassware, calorimeter, thermometer) and materials (e.g., chemical compounds and solutions), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection (e.g., wearing safety goggles)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement (e.g., SI units, imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places and significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., food and drug analyst, chemical safety officer, nurse practitioner, consumer protection specialist, metallurgy technologist, environmental and waste management technician, geochemist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Robert G. Ackman, Alice Wilson, Carol Ann Budd, Norman L. Bowen, Brian Evans Conway), to the fields under study

B. ORGANIC CHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. assess the social and environmental impact of organic compounds used in everyday life, and propose a course of action to reduce the use of compounds that are harmful to human health and the environment;

B2. investigate organic compounds and organic chemical reactions, and use various methods to represent the compounds;

B3. demonstrate an understanding of the structure, properties, and chemical behaviour of compounds within each class of organic compounds.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 assess the impact on human health, society, and the environment of organic compounds used in everyday life (e.g., polymers, nutritional supplements, food additives, pharmaceuticals, pesticides) [AI, C]

Sample issue: Organic solvents can dissolve many substances such as paint, oil, and grease. They are used to produce plastics, dyes, detergents, textiles, and pharmaceuticals. However, workers exposed to organic solvents may experience long-term effects on their health. Also, solvents from industrial spills and leaks can leach into soil and groundwater, posing serious health and environmental risks.

Sample questions: What methods should be used to safely dispose of volatile organic compounds? What WHMIS symbols or Household Hazardous Waste Symbols (HHWS) should appear on containers of pesticides? Why are organic compounds added to food products? What impact can these additives have on human health?

B1.2 propose a personal course of action to reduce the use of compounds that are harmful to human health and the environment (e.g., weed lawns by hand rather than using herbicides, use cloth bags for shopping to reduce the number of plastic bags in landfill sites, choose fuel-efficient or hybrid vehicles to reduce fossil fuel emissions) [AI, C]

Sample issue: Many Ontario communities have banned the use of pesticides. As a consequence of these by-laws, many homeowners are seeking alternative ways of controlling weeds in their lawns.

Sample questions: How long does it take for plastic garbage bags to decompose in a landfill site? What biodegradable materials can be used to replace polystyrene as a packaging material? What are some technologies and features that are making new cars more fuel-efficient?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to organic chemistry, including, but not limited to: *organic compound, functional group, saturated hydrocarbon, unsaturated hydrocarbon, structural isomer, stereoisomer,* and *polymer* [C]

B2.2 use International Union of Pure and Applied Chemistry (IUPAC) nomenclature conventions to identify names, write chemical formulae, and create structural formulae for the different classes of organic compounds, including hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, amides, and simple aromatic compounds [AI, C]

B2.3 build molecular models for a variety of simple organic compounds [PR, AI, C]

B2.4 analyse, on the basis of inquiry, various organic chemical reactions (e.g., production of esters, polymerization, oxidation of alcohols, multiple bonds in an organic compound, combustion reactions, addition reactions) [PR, AI]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 compare the different classes of organic compounds, including hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides, by describing the similarities and differences in names and structural formulae of the compounds within each class

B3.2 describe the similarities and differences in physical properties (e.g., solubility in different solvents, odour, melting point, boiling point) within each class of organic compounds

B3.3 explain the chemical changes that occur during various types of organic chemical reactions, including substitution, addition, elimination, oxidation, esterification, and hydrolysis

B3.4 explain the difference between an addition reaction and a condensation polymerization reaction

B3.5 explain the concept of isomerism in organic compounds, and how variations in the properties of isomers relate to their structural and molecular formulae

C. STRUCTURE AND PROPERTIES OF MATTER

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. assess the benefits to society and evaluate the environmental impact of products and technologies that apply principles related to the structure and properties of matter;

C2. investigate the molecular shapes and physical properties of various types of matter;

C3. demonstrate an understanding of atomic structure and chemical bonding, and how they relate to the physical properties of ionic, molecular, covalent network, and metallic substances.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 assess the benefits to society of technologies that are based on the principles of atomic and molecular structures (e.g., magnetic resonance imaging [MRI], infrared spectroscopy, X-ray crystallography, nuclear energy, medical applications of spectroscopy and mass spectrometry) [AI, C]

Sample issue: In medicine, radioisotopes are bonded with chemical compounds to form radioactive tracers, which are then injected into the patient's bloodstream. The radiation emitted by the tracers allows doctors to obtain images of organ systems, facilitating the early and accurate diagnosis of disease. However, to avoid radioactive contamination, care must be taken in the storage, use, and disposal of this material.

Sample questions: How does infrared spectroscopy aid in criminal investigations? How has the use of X-ray crystallography and mass spectrometry advanced our understanding of atomic and molecular structure? What social benefits are associated with such advances?

C1.2 evaluate the benefits to society, and the impact on the environment, of specialized materials that have been created on the basis of scientific research into the structure of matter and chemical bonding (e.g., bulletproof fabric, nanotechnologies, superconductors, instant adhesives) [AI, C]

Sample issue: Nanoparticles have many potential applications in medicine, including the improvement of drug delivery systems, the enhancement of diagnostic images, and use in surgical robotics, all of which could improve the effectiveness of our health care system. However, nanoparticle contamination can have a negative effect on the environment.

Sample questions: What precautions are taken to protect the health and safety of people working with nanoparticles? What properties of disposable diapers enable them to hold so much liquid? What impact has the widespread use of such diapers had on the environment? What impact has the development of synthetic fibres, such as nylon, had on society? What would your life be like if there were no plastics? In what ways has the invention of the silicon chip changed society?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to structure and properties of matter, including, but not limited to: *orbital*, *emission spectrum*, *energy level*, *photon*, and *dipole* [C]

C2.2 use the Pauli exclusion principle, Hund's rule, and the aufbau principle to write electron configurations for a variety of elements in the periodic table [AI, C]

C2.3 predict the shapes of simple molecules and ions (e.g., CH_4, SO_3, O_2, H_2O, NH_4^+), using the valence shell electron pair repulsion (VSEPR) model, and draw diagrams to represent their molecular shapes [AI, C]

C2.4 predict the polarity of various chemical compounds, based on their molecular shapes and the difference in the electronegativity values of the atoms [AI]

C2.5 predict the type of solid (ionic, molecular, covalent network, metallic) formed by a given substance in a chemical reaction, and describe the properties of that solid [AI]

C2.6 conduct an inquiry to observe and analyse the physical properties of various substances (e.g., salts, metals) and to determine the type of chemical bonding present in each substance [PR, AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 explain how experimental observations and inferences made by Ernest Rutherford and Niels Bohr contributed to the development of the planetary model of the hydrogen atom

C3.2 describe the electron configurations of a variety of elements in the periodic table, using the concept of energy levels in shells and subshells, as well as the Pauli exclusion principle, Hund's rule, and the aufbau principle

C3.3 identify the characteristic properties of elements in each of the *s*, *p*, and *d* blocks of the periodic table, and explain the relationship between the position of an element in the periodic table, its properties, and its electron configuration

C3.4 explain how the physical properties of a solid or liquid (e.g., solubility, boiling point, melting point, melting point suppression, hardness, electrical conductivity, surface tension) depend on the particles present and the types of intermolecular and intramolecular forces (e.g., covalent bonding, ionic bonding, Van der Waals forces, hydrogen bonding, metallic bonding)

C3.5 describe a Canadian contribution to the field of atomic and molecular theory (e.g., the work of Richard F.W. Bader of McMaster University on electronic density in small molecules; the work of Robert J. LeRoy of the University of Waterloo on the mathematical technique to determine the atomic radius of molecules known as the LeRoy Radius; the work of Ronald J. Gillespie of McMaster University on the VSEPR model)

D. ENERGY CHANGES AND RATES OF REACTION

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse technologies and chemical processes that are based on energy changes, and evaluate them in terms of their efficiency and their effects on the environment;

D2. investigate and analyse energy changes and rates of reaction in physical and chemical processes, and solve related problems;

D3. demonstrate an understanding of energy changes and rates of reaction.

SPECIFIC EXPECTATIONSP

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse some conventional and alternative energy technologies (e.g., fossil fuel–burning power plants, hydro-powered generators, solar panels, wind turbines, fuel cells), and evaluate them in terms of their efficiency and impact on the environment [AI, C]

Sample issue: The cooling of homes and commercial buildings in summer requires more energy than heating in the winter at peak times. Brownouts are more likely in summer than in winter. However, new technologies use deep lake water cooling as an alternative to conventional air conditioning systems in office towers. This significantly reduces energy use and its environmental impact.

Sample questions: What proportion of Ontario's energy needs is served by solar and wind technologies? What are the pros and cons of expanding the availability of these technologies? What types of chemical reactions occur in different types of fuel cells? What are the advantages and disadvantages, in terms of efficiency and environmental impact, of using corn to produce ethanol fuel?

D1.2 analyse the conditions (e.g., temperature, pressure, presence of a catalyst) required to maximize the efficiency of some common natural or industrial chemical reactions (e.g., decomposition, combustion, neutralization), and explain how the improved efficiency of the reaction contributes to environmental sustainability [AI, C]

Sample issue: Bleaches such as hydrogen peroxide and chlorine are used when fibres are processed into paper or textiles. Concentrations of these substances can harm the environment, but if enzymes are added to these processes as biocatalysts, fewer chemicals are needed, less energy is consumed, and there is less environmental impact.

Sample questions: How can you increase the rate of decomposition in a home composter? What can be done to improve the efficiency of an automobile that runs entirely on fossil fuels? Why is just a very small quantity of catalyst required in industrial processes? Why is the ozone layer still deteriorating despite the banning of chlorofluorocarbons (CFCs)?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to energy changes and rates of reaction, including, but not limited to: *enthalpy*, *activation energy*, *endothermic*, *exothermic*, *potential energy*, and *specific heat capacity* [C]

D2.2 write thermochemical equations, expressing the energy change as a ΔH value or as a heat term in the equation [AI, C]

D2.3 solve problems involving analysis of heat transfer in a chemical reaction, using the equation $Q = mc\Delta T$ (e.g., calculate the energy released in the combustion of an organic compound, and express the results in energy per mole of fuel [J/mol]) [AI, C]

D2.4 plan and conduct an inquiry to calculate, using a calorimeter, the heat of reaction of a substance (e.g., the heat of solution of ammonium nitrate, or of combustion of a hydrocarbon), compare the actual heat of reaction to the theoretical value, and suggest sources of experimental error [IP, PR, AI, C]

D2.5 solve problems related to energy changes in a chemical reaction, using Hess's law [AI]

D2.6 conduct an inquiry to test Hess's law (e.g., measure heats of reaction from the combustion of magnesium, and combine them to yield the ΔH value of the reaction) [PR, AI]

D2.7 calculate the heat of reaction for a formation reaction, using a table of standard enthalpies of formation and applying Hess's law [AI]

D2.8 plan and conduct an inquiry to determine how various factors (e.g., change in temperature, addition of a catalyst, increase in surface area of a solid reactant) affect the rate of a chemical reaction [IP, PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 compare the energy changes resulting from physical change (e.g., boiling water), chemical reactions (e.g., bleaching a stain), and nuclear reactions (e.g., fission, fusion), in terms of whether energy is released or absorbed

D3.2 compare the energy change from a reaction in which bonds are formed to one in which bonds are broken, and explain these changes in terms of endothermic and exothermic reactions

D3.3 explain how mass, heat capacity, and change in temperature of a substance determine the amount of heat gained or lost by the substance

D3.4 state Hess's law, and explain, using examples, how it is applied to find the enthalpy changes of a reaction

D3.5 explain, using collision theory and potential energy diagrams, how factors such as temperature, the surface area of the reactants, the nature of the reactants, the addition of catalysts, and the concentration of the solution control the rate of a chemical reaction

D3.6 describe simple potential energy diagrams of chemical reactions (e.g., the relationships between the relative energies of reactants and products and the activation energy of the reaction)

D3.7 explain, with reference to a simple chemical reaction (e.g., combustion), how the rate of a reaction is determined by the series of elementary steps that make up the overall reaction mechanism

E. CHEMICAL SYSTEMS AND EQUILIBRIUM

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse chemical equilibrium processes, and assess their impact on biological, biochemical, and technological systems;

E2. investigate the qualitative and quantitative nature of chemical systems at equilibrium, and solve related problems;

E3. demonstrate an understanding of the concept of dynamic equilibrium and the variables that cause shifts in the equilibrium of chemical systems.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse the optimal conditions for a specific chemical process related to the principles of equilibrium that takes place in nature or is used in industry (e.g., the production of sulfuric acid, electrolyte balance in the human body, sedimentation in water systems) [AI, C]

Sample issue: The principle of dynamic equilibrium is used in industrial processes to maximize the concentration of products and minimize leftover reactants. Industrial chemists determine ideal pressure and temperature conditions, and proper catalysts, so that fewer materials and less energy are used.

Sample questions: Why are low temperature conditions not used with exothermic reactions? How do chemicals dissolved in human blood help maintain a blood pH level between 7.2 and 7.4?

E1.2 assess the impact of chemical equilibrium processes on various biological, biochemical, and technological systems (e.g., remediation in areas of heavy metal contamination, development of gallstones, use of buffering in medications, use of barium sulfate in medical diagnosis) [AI, C]

Sample issue: Heavy metals such as copper, lead, and zinc can accumulate to toxic levels in the human body. A process called chelation, which causes a chemical reaction involving an equilibrium shift, removes the metals from the body before permanent organ damage occurs.

Sample questions: Why are headache tablets buffered? Why is barium sulfate safe to use for X-rays of the digestive system even though barium ions are poisonous? How do kidney stones form?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to chemical systems and equilibrium, including, but not limited to: *homogeneous, closed system, reversible reaction, equilibrium constant, equilibrium concentration, molar solubility,* and *buffer* [C]

E2.2 predict, applying Le Châtelier's principle or the reaction quotient for a given reaction, how various factors (e.g., changes in volume, temperature, or concentration of reactants or products in a solution) would affect a chemical system at equilibrium, and conduct an inquiry to test those predictions [PR, AI]

E2.3 conduct an inquiry to determine the value of an equilibrium constant for a chemical reaction (e.g., K_{eq} for iron(III) thiocyanate, K_{sp} for calcium hydroxide, K_a for acetic acid) [PR, AI]

E2.4 solve problems related to equilibrium by performing calculations involving concentrations of reactants and products (e.g., K_{eq}, K_{sp}, K_a, pH, pOH, K_p, K_b) [AI]

E2.5 solve problems related to acid–base equilibrium, using acid–base titration data and the pH at the equivalence point [AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 explain the concept of dynamic equilibrium, using examples of physical and chemical equilibrium systems (e.g., liquid–vapour equilibrium, weak electrolytes in solution, reversible chemical reactions)

E3.2 explain the concept of chemical equilibrium and how it applies to the concentration of reactants and products in a chemical reaction at equilibrium

E3.3 explain Le Châtelier's principle and how it applies to changes to a chemical reaction at equilibrium

E3.4 identify common equilibrium constants, including K_{eq}, K_{sp}, K_w, K_a, K_b, and K_p, and write the expressions for each

E3.5 use the ionization constant of water (K_w) to calculate pH, pOH, $[H_3O^+]$, and $[OH^-]$ for chemical reactions

E3.6 explain the Brønsted-Lowry theory of acids and bases

E3.7 compare the properties of strong and weak acids, and strong and weak bases, using the concept of dynamic equilibrium

E3.8 describe the chemical characteristics of buffer solutions

F. ELECTROCHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse technologies and processes relating to electrochemistry, and their implications for society, health and safety, and the environment;

F2. investigate oxidation-reduction reactions using a galvanic cell, and analyse electrochemical reactions in qualitative and quantitative terms;

F3. demonstrate an understanding of the principles of oxidation-reduction reactions and the many practical applications of electrochemistry.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 assess, on the basis of research, the viability of using electrochemical technologies as alternative sources of energy (e.g., fuel cells for emergency power generation or as power sources in remote locations), and explain their potential impact on society and the environment [IP, PR, AI, C]

Sample issue: Hydrogen fuel cells use hydrogen as the fuel and oxygen as the oxidant, and produce water, rather than environmentally harmful greenhouse gases, as waste. Although some cars run on such cells, practical problems must be resolved before this source of energy is commonly used in the transportation sector.

Sample questions: What is the capacity of a standard rechargeable battery before it has to be recharged? What methods should be used to dispose of depleted batteries? What impact has the use of rechargeable batteries in portable electronic devices had on society?

F1.2 analyse health and safety issues involving electrochemistry (e.g., corrosion of metal pipes in drinking water systems) [AI, C]

Sample issue: Corrosion is a leading cause of structural degradation of bridges and roadways. Not only does rust weaken metal structures, but as it builds up it forces apart connecting parts of the structure, causing the structure to fail and risking public safety. Yet, methods used to prevent corrosion may also have negative effects on human health.

Sample questions: What health and safety hazards are associated with waste generated by electroplating companies? Why do metal orthodontic braces not corrode? What are some of the toxic substances that can escape from electronic waste into the environment? What are the potential effects of these poisons on our health?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to electrochemistry, including, but not limited to: *half-reaction*, *electrochemical cell*, *reducing agent*, *oxidizing agent*, *redox reaction*, and *oxidation number* [C]

F2.2 conduct an inquiry to analyse, in qualitative terms, an oxidation-reduction (redox) reaction [PR, AI, C]

F2.3 write balanced chemical equations for oxidation-reduction reactions, using various methods including oxidation numbers of atoms and the half-reaction method of balancing [AI, C]

F2.4 build a galvanic cell and measure its cell potential [PR, AI]

F2.5 analyse the processes in galvanic cells, and draw labelled diagrams of these cells to show the oxidation or reduction reaction that occurs in each of the half-cells, the direction of electron flow, the electrode polarity (anode and cathode), the cell potential, and the direction of ion movement [AI, C]

F2.6 predict the spontaneity of redox reactions, based on overall cell potential as determined using a table of standard reduction potentials for redox half-reactions [AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 explain redox reactions in terms of the loss and gain of electrons and the associated change in oxidation number

F3.2 identify the components of a galvanic cell, and explain how each component functions in a redox reaction

F3.3 describe galvanic cells in terms of oxidation and reduction half-cells whose voltages can be used to determine overall cell potential

F3.4 explain how the hydrogen half-cell is used as a standard reference to determine the voltages of another half-cell

F3.5 explain some applications of electrochemistry in common industrial processes (e.g., in refining metals such as aluminum and zinc; in the production of hydrogen)

F3.6 explain the corrosion of metals in terms of an electrochemical process, and describe some common corrosion-inhibiting techniques (e.g., painting, galvanizing, cathodic protection)

Chemistry, Grade 12

College Preparation SCH4C

This course enables students to develop an understanding of chemistry through the study of matter and qualitative analysis, organic chemistry, electrochemistry, chemical calculations, and chemistry as it relates to the quality of the environment. Students will use 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 the effects of technological applications and processes on society and the environment.

Prerequisite: Science, Grade 10, Academic or Applied

Big Ideas

Matter and Qualitative Analysis
- The properties of matter can be predicted and analysed qualitatively.
- Substances can be identified based on their distinct properties.
- Qualitative analysis of matter is used in many different fields of endeavour.

Organic Chemistry
- Organic compounds have predictable chemical and physical properties determined by their respective structures.
- Organic compounds can be synthesized by living things or through artificial processes.
- Organic chemical reactions and their applications have significant implications for society, human health, and the environment.

Electrochemistry
- Oxidation and reduction are paired chemical reactions in which electrons are transferred from one substance to another in a predictable way.
- The control and applications of oxidation and reduction reactions have significant implications for society and the environment.

Chemical Calculations
- Relationships in chemical reactions can be described quantitatively.
- Quantitative relationships of chemical reactions have applications in the home, workplace, and the environment.

Chemistry in the Environment
- Air and water quality can be affected by both natural processes and human activities.
- Quantitative relationships of chemical reactions can be used to assess air and water quality.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Matter and Qualitative Analysis	Organic Chemistry	Electrochemistry	Chemical Calculations	Chemistry in the Environment
Matter	✓	✓	✓	✓	✓
Energy	✓		✓		✓
Systems and Interactions		✓		✓	
Structure and Function		✓	✓		✓
Sustainability and Stewardship	✓	✓	✓	✓	✓
Change and Continuity	✓				

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., spectroscope, centrifuge, burettes, meters) and materials (e.g., acid/base indicators, solubility tables, galvanic cells), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials (e.g., safely disposing of organic solutions); and by using appropriate personal protection (e.g., wearing safety goggles)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation (e.g., represent ionic and molecular compounds by their accepted formulae and names), and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., environmental technologist, pharmacy technician, electroplating technician, green building or renewable energy technician, veterinary technician, biochemical technologist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Jed Harrison, Louis Slotin, Paul Kebarle, James Robert Bolton, Brian Evans Conway, Lee Wilson), to the fields under study

B. MATTER AND QUALITATIVE ANALYSIS

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. evaluate the effects of chemical substances on the environment, and analyse practical applications of qualitative analysis of matter;

B2. investigate matter, using various methods of qualitative analysis;

B3. demonstrate an understanding of the basic principles of qualitative analysis of matter.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 evaluate the risks and benefits to the environment of some commonly used chemical substances (e.g., substances used in fireworks, fire extinguishers, "green" cleaning products) [AI, C]

Sample issue: Numerous synthetic fertilizers are available for residential lawns and gardens, all of which claim good results based on their chemical composition. Although these fertilizers provide nutrients that are essential for healthy plants and soil, they may also contain harmful chemicals that can pose risks to the environment.

Sample questions: What chemical substances can be removed from drinking water by household water purification systems? What impact do chemical substances used in drive-through car washes have on the local environment? Why are packing chips that are made from cornstarch better for the environment than those made from polystyrene?

B1.2 analyse, on the basis of research, applications of qualitative analysis of matter in various fields of endeavour (e.g., in law enforcement to detect drugs or identify counterfeit money; in the manufacture of food products) [IP, PR, AI, C]

Sample issue: Forensic chemists use many qualitative analysis techniques in their work, including spectroscopy to identify controlled substances such as chemicals, drugs, and explosives. Spectroscopy can detect minute traces of substances, so care must be taken in handling samples to ensure that they are not contaminated during transport, storage, or analysis.

Sample questions: What substances do environmental chemists test for in the soil of industrial sites that have been rezoned for residential use? What different chemical compounds are used to create some of the desired effects in fireworks? What types of particulate matter do air quality testers measure when there is the potential for a smog alert?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to qualitative analysis of matter, including, but not limited to: *double displacement*, *precipitate*, and *energy level* [C]

B2.2 use a table of solubility rules to write chemical equations for double displacement reactions and to write balanced net ionic equations for chemical reactions [AI, C]

B2.3 investigate precipitation reactions and flame tests, using qualitative analysis instruments, equipment, and techniques (e.g., gas discharge tubes, high-voltage electrical sources, spectroscope, centrifuge) [PR, AI]

B2.4 conduct qualitative analyses of an unknown sample (e.g., a household or workplace chemical), using a flow chart and experimental procedures, including flame tests and precipitation reactions, to determine the presence of metal ions [PR, AI]

B2.5 identify an unknown gas sample (e.g., hydrogen, helium, neon) by observing its emission spectrum and comparing it to the spectra of known gases [PR, AI]

B2.6 use a table of solubility rules to predict if a precipitate will form in a given chemical reaction, and identify the precipitate formed [AI]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 explain the relationship between the atomic number and the mass number of an element, and the difference between isotopes and radioisotopes of an element

B3.2 describe various types of chemical reactions, including synthesis, decomposition, single displacement, and double displacement reactions

B3.3 explain basic procedures used in qualitative analysis of elements and compounds, including flame tests, precipitation reactions, and the observation of emission spectra

B3.4 relate observations from investigations using flame tests and emission spectra to the concept of quanta of energy proposed by Neils Bohr

C. ORGANIC CHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. evaluate the impact on society, human health, and the environment of products made using organic compounds;

C2. investigate the physical and chemical properties of organic compounds, and analyse some common organic chemical reactions;

C3. demonstrate an understanding of the structure and the physical and chemical properties of organic compounds.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 identify various materials and products used in everyday life that are made from organic compounds (e.g., synthetic fabrics, drugs, pesticides, cosmetics, organic solvents, car parts, artificial hearts), and assess the benefits of those products for society, as well as the health hazards they pose [AI, C]

Sample issue: Organic compounds are present in a wide variety of pharmaceuticals and natural health products that can contribute to people's health. However, some of the organic chemicals in these products may not be as natural or healthy as advertised, and they can have adverse affects on some people.

Sample questions: Why are organic compounds often added to food products? What are the benefits, and potential health risks, to farmers of spraying pesticides on their crops? What are the health risks of eating food that has been heated in plastic containers in the microwave? What are the benefits and risks to our health of taking some common pain relief medications?

C1.2 research a useful product made from one or more organic substances (e.g., CDs, made from crude oil), and assess the environmental impact of the production, use, and disposal of the product [IP, PR, AI, C]

Sample issue: We depend on plastics in every area of our lives, from food packaging to construction materials to DVDs. However, the manufacture of plastics involves the release of chemical pollutants and greenhouse gases into the environment, and huge quantities of plastic trash are now being found in our oceans.

Sample questions: What is the environmental impact of the production, use, and disposal of plastic water bottles? What impact does the vulcanization of rubber have on the environment? What are the risks and benefits to the environment of the production of synthetic fibres for the textile industry?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to organic chemistry, including, but not limited to: *electronegativity*, *covalent bond*, and *functional group* [C]

C2.2 draw Lewis structures to represent the covalent bonds in some simple organic molecules (e.g., CH_4) [AI, C]

C2.3 build molecular models of, and create structural formulae for, some simple organic molecules (e.g., methane, butane, ethyne) [PR, AI, C]

C2.4 conduct an inquiry to determine the physical and chemical properties of some common organic compounds (e.g., solubility [in polar and non-polar solvents], conductivity, odour, combustibility) [PR, AI]

C2.5 conduct an inquiry to demonstrate separation of a mixture of liquids by distillation [PR]

C2.6 conduct an inquiry to identify some of the products of the combustion of a hydrocarbon and an alcohol [PR, AI]

C2.7 conduct an inquiry to synthesize a common organic compound (e.g., produce an ester, make soap) [PR]

C2.8 predict the nature of a bond (e.g., non-polar covalent or polar covalent), using the electronegativity values of atoms (e.g., H_2, Cl_2, O_2, H_2O, CH_4, CH_3OH) [AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 describe the unique characteristics of the carbon atom in terms of covalent bonding

C3.2 identify functional group structures that define common classes of organic compounds (e.g., alkenes, alkanes, alkynes, alcohols, aldehydes, ketones, carboxylic acids, esters, amines)

C3.3 explain the general properties (e.g., polarity, solubility in water) of molecules that contain oxygen or nitrogen

C3.4 use structural formulae to describe some simple organic chemical reactions (e.g., addition, substitution, combustion)

C3.5 explain how the physical properties of a substance affect the processes used to separate organic chemical substances (e.g., distillation of crude oil, distillation of alcohols)

C3.6 identify the first ten hydrocarbons of the alkanes, the alkenes, and the alkynes by their names and structural formulae, using International Union of Pure and Applied Chemistry (IUPAC) nomenclature for alkanes, alkenes, and alkynes

C3.7 explain the dangers associated with the use of organic solvents (e.g., dry-cleaning compounds, paint thinners, glue solvents, nail polish remover), and some general precautions related to their use

D. ELECTROCHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse technological applications or processes relating to oxidation-reduction reactions, and assess their impact on the environment;

D2. investigate the oxidation-reduction reaction that occurs in a galvanic cell;

D3. demonstrate an understanding of the concepts of oxidation and reduction, and the principles of oxidation-reduction reactions.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse, on the basis of research, a technological application that is based on the oxidation-reduction (redox) reaction that occurs in galvanic cells (e.g., in cardiac pacemakers, batteries, electroplating) [IP, PR, AI, C]

Sample issue: Hydrogen fuel cells use a redox reaction that produces water, rather than environmentally harmful greenhouse gases, as waste. Although some cars could run on fuel cells, practical problems, such as the storage and cost of producing hydrogen, currently limit the usefulness of this technology in the transportation sector.

Sample questions: What chemical reactions occur in rechargeable and non-rechargeable batteries? How do different technologies use different types of galvanic cells for their energy? How does the redox reaction occur in the electroplating process? Why is this reaction necessary?

D1.2 analyse, on the basis of research, the causes of metal corrosion, and assess the environmental impact of some techniques used to protect metals from corrosion (e.g., rustproofing, painting, cathodic protection, galvanization) [IP, PR, AI, C]

Sample issue: The maintenance of large span-bridges over salt water has always been challenging, because the salt water spray causes corrosion. Newer bridges use support structures that have been protected from corrosion, but long-term studies have not been done on the impact of these methods on the environment.

Sample questions: What are some of the techniques used to protect metals from corrosion? What are the benefits and risks to the environment of the electroplating of metals? Why do metal orthodontic braces not corrode?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to electrochemistry, including, but not limited to: *oxidation*, *anode*, and *electrolyte* [C]

D2.2 build a galvanic cell and measure its voltage [PR, AI]

D2.3 analyse the processes in galvanic cells, and draw labelled diagrams of these cells to show the oxidation or reduction reaction that occurs in each of the half-cells, the direction of electron flow, the location of the electrodes, and the direction of ion movement [AI, C]

D2.4 design and conduct an inquiry to determine the factors that affect rate of corrosion of a metal (e.g., stress on the metal, contact between two metals, surface oxide, the nature of the electrolyte, the nature of the metal) [IP, PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the concepts of oxidation and reduction in terms of the chemical changes that occur during redox reactions

D3.2 describe the components of a galvanic cell, and explain how each component functions in a redox reaction

D3.3 describe the chemical reaction that results in the corrosion of metal

E. CHEMICAL CALCULATIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse processes in the home, the workplace, or the environmental sector that use chemical quantities and calculations, and assess the importance of accuracy in chemical calculations;

E2. investigate chemical compounds and chemical reactions using appropriate techniques of quantitative analysis, and solve related problems;

E3. demonstrate an understanding of the mole concept and its quantitative relationships in chemical reactions.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse processes in the home, the workplace, or the environmental sector that require an understanding of accurate chemical calculations (e.g., baking according to a recipe; manufacturing items such as fertilizer, paint, pharmaceuticals; testing water quality in a public pool) [AI, C]

Sample issue: Farmers use fertilizers that contain nitrogen and phosphorus to fertilize their crops. Although these nutrients are needed by the crops for growth, too much fertilizer can harm crops and potentially run off into water systems and contribute to the eutrophication of ponds and lakes.

Sample questions: What are the potential effects of adding too much or too little chlorine to drinking water at a water purification plant or private well? Why is it important to have the correct quantities of each tint when mixing paint colours? How would a slight miscalculation affect the paint colour?

E1.2 assess, on the basis of research, the importance of quantitative accuracy in the concentration of solutions used for medical purposes or personal care (e.g., cough syrup, intravenous solutions, sunscreen) [IP, PR, AI, C]

Sample issue: The components of hair colour products are carefully calculated to achieve a certain outcome within a specific time. However, if these variables are changed by the user, or if the hair has recently been chemically processed, unintended results can occur.

Sample questions: Why is it important to follow the dosage instructions on prescription medication and over-the-counter drugs? Why is it important to understand which type of sunscreen is best to use for your specific skin type? What does the SPF factor indicate about the active ingredients in sunscreen?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to stoichiometry, including, but not limited to: *molar mass*, *molar concentration*, *percentage yield*, and *Avogadro's number* [C]

E2.2 calculate the molar mass of simple compounds with the aid of the periodic table [AI]

E2.3 convert the quantity of chemicals in simple chemical reactions from number of particles to number of moles and mass, using the mole concept [AI]

E2.4 solve problems involving relationships between the following variables in a chemical reaction: quantity in moles, number of particles, atomic mass, concentration of solution, and volume of solution [AI]

E2.5 solve problems involving stoichiometric relationships in balanced chemical equations [AI]

E2.6 conduct an inquiry to determine the actual yield, theoretical yield, and percentage yield of the products of a chemical reaction (e.g., a chemical reaction between steel wool and copper(II) sulfate solution), assess the effectiveness of the procedure, and suggest sources of experimental error [PR, AI]

E2.7 use qualitative observations of a chemical reaction to identify the chemical changes, presence of limiting reagents, and the products occurring in a chemical reaction (e.g., aluminum reacting with copper(II) chloride solution, steel wool reacting with oxygen) [PR, AI]

E2.8 prepare aqueous solutions of given concentrations (e.g., concentrations expressed in grams per litre or moles per litre) by dissolving a solid solute in a solvent or by diluting a concentrated solution (e.g., a stock solution) [PR, AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe the relationships between Avogadro's number, the mole concept, and the molar mass of any given substance

E3.2 describe some possible sources of experimental error in an investigation of a chemical reaction, and explain how the errors would affect the percentage yield of products of the reaction

E3.3 explain the relationships between the mole concept, the values of coefficients, the number of particles, and the mass of substances in balanced chemical equations

E3.4 explain the concept of molar concentration of a solution, using appropriate units of measure

E3.5 explain the concept of a limiting reagent in a chemical reaction, using examples of chemical processes from everyday life (e.g., synthesis of aspirin, synthesis of ammonia)

F. CHEMISTRY IN THE ENVIRONMENT

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. evaluate the importance of government regulations, scientific analyses, and individual actions in improving air and water quality, and propose a personal plan of action to support these efforts;

F2. investigate chemical reactions, using appropriate techniques of quantitative analysis;

F3. demonstrate an understanding of chemical reactions that occur in the environment as a result of both natural processes and human activities.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 evaluate, on the basis of research, the effectiveness of government initiatives or regulations (e.g., the Great Lakes Action Plan), and the actions of individuals (e.g., use of public transportation), intended to improve air and water quality, and propose a personal action plan to support these efforts [IP, PR, AI, C]

Sample issue: The Yellow Fish Road is a nationwide program in which volunteers paint yellow fish symbols by storm drains to remind people that material poured into the drains flows directly into our local waterways, and that they should not pour hazardous substances down the drains. However, not everyone is aware of the symbolism of the fish, so the program may not be as effective as it could be.

Sample questions: How can your personal actions influence the air or water quality in your local area? Why have government initiatives, such as mass transit in urban areas, not been readily accepted by everyone? What can be done to encourage more people to use mass transit? What plans do local conservation authorities have to improve water quality in lakes, rivers, and streams in your local area? How effective are these plans?

F1.2 evaluate the importance of quantitative chemical analysis in assessing air and water quality (e.g., the use of Environment Canada's Air Quality Index to determine when smog advisories need to be issued; systems to monitor the quality of drinking water), and explain how these analyses contribute to environmental awareness and responsibility [AI, C]

Sample issue: Traditional stationary monitoring stations may not be able to supply sufficient data to reflect the differences in air quality from one location to another. However, researchers in Ontario now use mobile air quality monitors to measure vehicle emissions in high traffic areas and "hot spots" where vehicles idle for long periods of time. These data can be used to develop more precise air quality indices.

Sample questions: How can increased monitoring and reporting of air and water pollution influence the actions of individuals? Why are present chemical analyses not sufficient to detect and quantify all organic and inorganic contaminants in the water supply? How does WHMIS aid in minimizing damage to the environment and ensuring the safety of individuals in a case of an industrial accident?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to chemical analysis and chemistry in the environment, including, but not limited to: *ozone*, *hard water*, *titration*, *pH*, *ppm*, and *ppb* [C]

F2.2 write balanced chemical equations to represent the chemical reactions involved in the neutralization of acids and bases [AI, C]

F2.3 conduct an acid–base titration to determine the concentration of an acid or a base (e.g., the concentration of acetic acid in vinegar) [PR, AI]

F2.4 conduct an inquiry, using available technology (e.g., probewear) or chemical tests, to detect the presence of inorganic substances in various samples of water [PR, AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 identify major and minor chemical components of Earth's atmosphere

F3.2 identify gases and particulates that are commonly found in the atmosphere, and explain how they affect air quality (e.g., greenhouse gases, tropospheric and stratospheric ozone, carbon monoxide, chlorofluorocarbons, soot)

F3.3 state and explain the Arrhenius definition of acids and bases

F3.4 explain the difference between strong and weak acids, and between strong and weak bases, in terms of degree of ionization

F3.5 identify the gas emissions that are the major contributors to acid precipitation, and explain the steps in the formation of acid rain

F3.6 explain the difference between the concepts of strength and concentration when referring to solutions of acids and bases

F3.7 identify inorganic substances that can be found dissolved in water as a result of natural processes and human activities (e.g., hard water contains metal ions)

EARTH AND SPACE SCIENCE

Earth and Space Science, Grade 12

University Preparation SES4U

This course develops students' understanding of Earth and its place in the universe. Students will investigate the properties of and forces in the universe and solar system and analyse techniques scientists use to generate knowledge about them. Students will closely examine the materials of Earth, its internal and surficial processes, and its geological history, and will learn how Earth's systems interact and how they have changed over time. Throughout the course, students will learn how these forces, processes, and materials affect their daily lives. The course draws on biology, chemistry, physics, and mathematics in its consideration of geological and astronomical processes that can be observed directly or inferred from other evidence.

Prerequisite: Science, Grade 10, Academic

Big Ideas

Astronomy (Science of the Universe)

- The development of more sophisticated technologies has enabled us to achieve a deeper, more thorough understanding of the origin and evolution of the universe.
- Scientific theories about the universe are refined and altered as new evidence is discovered.

Planetary Science (Science of the Solar System)

- Space exploration and the technologies that have been developed to facilitate it have had positive and negative effects on society, the economy, and the environment.
- Space exploration presents many hazards.
- Interactions among bodies within the solar system have an impact on the existence of life.

Recording Earth's Geological History

- Earth is very old, and its atmosphere, hydrosphere, and lithosphere have undergone many changes over time.
- Changing conditions on Earth over time have had positive and negative effects on life on the planet.

Earth Materials

- Exploration for and extraction and refining of materials from below the surface of Earth have positive and negative effects on the economy, society, and the environment.
- Different types of rocks have different origins, properties, characteristics, and uses.

Geological Processes

- Earth's lithosphere is constantly changing as the result of natural phenomena and human activity.
- Specialized technologies have enabled us to increase our knowledge and understanding of Earth's structure and have improved the ability of scientists to monitor and predict changes in the lithosphere.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Astronomy (Science of the Universe)	Planetary Science (Science of the Solar System)	Recording Earth's Geological History	Earth Materials	Geological Processes
Matter	✓	✓	✓	✓	✓
Energy	✓	✓	✓	✓	
Systems and Interactions		✓	✓		✓
Structure and Function				✓	
Sustainability and Stewardship		✓	✓	✓	✓
Change and Continuity	✓	✓	✓		✓

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers and Canadian contributions related to the fields of science under study.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., hand lens, spectrographs, rock hammers) and materials (e.g., star charts, geological maps, mineral identification kits), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory and field work practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials (e.g., following safety procedures when collecting samples; using materials safely when identifying minerals and rocks); and by using appropriate personal protection (e.g., wearing safety goggles when testing rock or mineral samples; using proper protective eyewear when observing the sun)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, and adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate observations and data from laboratory and other sources (e.g., field work), and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources (e.g., personal communication), using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., use appropriate time scales when representing geological time, or appropriate units to represent astronomical distances)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the field of science under study (e.g., astronomer, paleontologist, astrophysicist, geologist, professor, planetarium curator) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadian scientists (e.g., Alice Wilson, George M. Dawson, Thomas Edvard Krogh, William E. Logan, Richard Bond, Helen Sawyer Hogg, Joseph B. Tyrrell), to the fields under study

B. ASTRONOMY (SCIENCE OF THE UNIVERSE)

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse the development of technologies that have contributed to our understanding of the universe, and evaluate the impact of milestones in astronomical theory or knowledge on the scientific community;

B2. investigate and analyse the properties of the universe, particularly the evolution and properties of stars, in both qualitative and quantitative terms;

B3. demonstrate an understanding of the origin and evolution of the universe, the principal characteristics of its components, and techniques used to study those components.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse a major milestone in astronomical knowledge or theory (e.g., the discovery of the red shift in the spectra of galaxies; the knowledge gathered from the particle accelerator experiments at CERN in Switzerland), and explain how it revolutionized thinking in the scientific community [AI, C]

Sample issue: Prior to Copernicus, astronomers generally believed that Earth was the centre of the universe. Copernicus's heliocentric thesis had a revolutionary impact not only on astronomy but on other areas of science as well.

Sample questions: How did the approach used by Galileo to support heliocentric thesis differ from Greek speculative philosophy about the structure of the universe? What impact did Galileo's findings have on other astronomers and on scientists in general? How did Kepler's calculations and mathematical models differ from earlier explanations of celestial motion? How did they influence subsequent astronomers? How has Brahe's work affected our view of our planet?

B1.2 analyse why and how a particular technology related to astronomical research was developed and how it has been improved over time (e.g., the evolution from optical to radio telescopes and to the Hubble telescope) [AI, C]

Sample issue: In 1933, K.G. Jansky built a radio telescope to identify sources of static interference affecting telephone transmission. He discovered that much of the static came from deep within the Milky Way. Radio telescopes have since been modified to include large parabolic dishes, which are used to study pulsars, quasars, and black holes.

Sample questions: What technologies in astronomical research were originally developed for military uses? In what ways have they been refined for scientific use? How has light collection and focusing improved with the use of the liquid mercury telescope operated by the University of British Columbia and Laval University? Why was the Sudbury Neutrino Observatory built? How have developments over time improved its usefulness?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to astronomy, including, but not limited to: *Doppler effect, electromagnetic radiation, protostar, celestial equator, ecliptic, altitude and azimuth,* and *right ascension and declination* [C]

B2.2 locate observable features of the night sky using star charts, computer models, or direct observation, and record the location of these features using astronomical terms (e.g., celestial equator, ecliptic) and systems (e.g., altitude and azimuth, right ascension and declination) [PR, C]

B2.3 analyse spectroscopic data mathematically or graphically to determine various properties of stars (e.g., determine surface temperature from peak wavelength using Wein's law; predict chemical composition from spectral absorption lines; determine motion using the Doppler effect) [AI, C]

B2.4 use the Hertzsprung-Russell diagram to determine the interrelationships between the properties of stars (e.g., between mass and luminosity, between colour and luminosity) and to investigate their evolutionary pathways [PR, AI]

B2.5 investigate, in quantitative terms, properties of stars, including their distance from Earth (using the parallax method), surface temperature, absolute magnitude, and luminosity [PR, AI]

B2.6 investigate, using photographs or diagrams, the basic features of different types of galaxies (e.g., elliptical, spiral, barred spiral, irregular, peculiar), including the Milky Way [PR]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 describe the theoretical and evidential underpinnings of the big bang theory (e.g., the theory that cosmic microwave background radiation is an echo of the big bang; physical evidence of the mass of the universe, and the relationship between mass and gravity) and their implications for the evolution of the universe

B3.2 explain the scale of distances between celestial bodies (e.g., with reference to astronomical units, light years, and parsecs) and the methods astronomers use to determine these distances (e.g., stellar parallax, cepheid variables)

B3.3 describe the characteristics of electromagnetic radiation (e.g., the relationship between wavelength, frequency, and energy) and the ways in which each region of the electromagnetic spectrum is used in making astronomical observations (e.g., X-rays in the search for black holes; infrared radiation to see through interstellar dust)

B3.4 explain how stars are classified on the basis of their surface temperature, luminosity, and chemical composition

B3.5 explain, with reference to a specific star (e.g., Rigel, Sirius, Arcturus), how astronomers use techniques to determine the properties of stars (e.g., mass, diameter, magnitude, temperature, luminosity)

B3.6 describe the sequence of events in the life cycle of a star, from its formation to the main sequence phase and beyond, with specific reference to energy sources and forces involved

B3.7 explain the relationship between the type of death of a star and the star's initial mass (e.g., a star with a low mass will form a planetary nebula and a white dwarf)

C. PLANETARY SCIENCE (SCIENCE OF THE SOLAR SYSTEM)

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse political, economic, and environmental issues related to the exploration and study of the solar system, and how technology used in space exploration can be used in other areas of endeavour;

C2. investigate features of and interactions between bodies in the solar system, and the impact of these features and interactions on the existence of life;

C3. demonstrate an understanding of the internal (geological) processes and external (cosmic) influences operating on bodies in the solar system.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse political considerations related to, and economic and environmental consequences (actual and/or potential) of, exploration of the solar system (e.g., political pressures underlying the original Space Race; the ability to monitor environmental conditions from space) [AI, C]

Sample issue: As we deplete Earth's natural resources, researchers are studying the feasibility of supplementing those resources through space mining. Asteroids and other bodies in the solar system are potentially rich sources of minerals and other valuable substances, but their exploitation raises a range of legal, economic, environmental, and technological questions.

Sample questions: What are some of the dangers to terrestrial life and to space travellers of the orbital debris from space travel and study? What types of factors affect government decisions about allocating funds for space exploration? Is the investment made in space exploration money well spent? Why or why not?

C1.2 analyse, on the basis of research, a specific technology that is used in space exploration and that has applications in other areas of research or in the environmental sector (e.g., Canadian satellites and robotics, spacecraft technologies, ground base and orbital telescopes, devices to mitigate the effects of the space environment on living organisms), and communicate their findings [IP, PR, AI, C]

Sample issue: The Canadarms were developed for space shuttle missions and the International Space Station. However, the robotic arms have other applications, including inspecting and cleaning up hazardous substances, servicing nuclear power plants, repairing pipelines on the ocean floor, mining in areas too inhospitable for humans, and conducting remote or microsurgery.

Sample questions: How are Landsat and radar from space shuttles used in archaeological research, costal studies, and the monitoring of natural disasters? How can technologies developed for space travel be used in water purification and waste treatment on Earth? How is remote sensing used to monitor atmospheric changes, such as changes in the ozone layer? How is remote sensing used to monitor changes to ecosystems?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to planetary science, including, but not limited to: *solar system*, *geocentric*, *heliocentric*, *geodesy*, *geosynchronous*, *eccentricity*, *apogee*, *aphelion*, *perigee*, and *perihelion* [C]

C2.2 identify geological features and processes that are common to Earth and other bodies in the solar system (e.g., craters, faults, volcanic eruptions), and create a model or illustration to show these features, using data and images from satellites and space probes [PR, AI, C]

C2.3 use an inquiry or research process to investigate the effects of various forms of radiation and high-energy particles on bodies, organisms, and devices within the solar system (e.g., the effects of cosmic rays on atmospheric phenomena, of ultraviolet light on human and animal eyes and skin, of solar wind on radio communications) [IP, PR]

C2.4 investigate the ways in which interactions between solid bodies have helped to shape the solar system, including Earth (e.g., the accretion of minor bodies, the formation of moons, the formation of planetary rings) [PR]

C2.5 investigate the properties of Earth that protect life from hazards such as radiation and collision with other bodies (e.g., Earth's orbital position helps protect it from asteroids, some of which are deflected by the Jovian planets; Earth's magnetic field protects the planet from solar wind; atmospheric ozone minimizes incoming ultraviolet radiation) [PR]

C2.6 investigate techniques used to study and understand objects in the solar system (e.g., the measurement of gravitational pull on space probes to determine the mass of an object, the use of spectroscopy to study atmospheric compositions, the use of the global positioning system to track plate movement and tectonic activity from space) [PR]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 explain the composition of the solar system (e.g., the sun, terrestrial inner planets, the asteroid belt, gas giant outer planets, the Kuiper belt, the scattered disc, the heliopause, the Oort cloud), and describe the characteristics of each component

C3.2 identify and explain the classes of objects orbiting the sun (e.g., planets, dwarf planets, small solar system bodies [SSSBs])

C3.3 explain the formation of the solar system with reference to the fundamental forces and processes involved (e.g., how gravitational force led to the contraction of the original solar nebula)

C3.4 identify the factors that determined the properties of bodies in the solar system (e.g., differences in distance from the sun result in temperature variations that determine whether substances on a planet, moon, or other body are solid or gaseous)

C3.5 identify and explain the properties of celestial bodies within or beyond the solar system, other than Earth, that might support the existence of life (e.g., the possible existence of liquid water on Europa; the proximity of a body to its host star)

C3.6 compare Earth with other objects in the solar system with respect to properties such as mass, size, composition, rotation, magnetic field, and gravitational field

C3.7 identify Kepler's laws, and use them to describe planetary motions (e.g., the shape of their orbits; differences in their orbital velocity)

C3.8 identify Newton's laws, and use them to explain planetary motion

C3.9 describe the major external processes and phenomena that affect Earth (e.g., radiation and particles from the "quiet" and "active" sun; cosmic rays; gravity of the sun and moon; asteroidal and cometary debris, including their force, energy, and matter)

D. RECORDING EARTH'S GEOLOGICAL HISTORY

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse, with reference to geological records, the relationship between climate, geology, and life on Earth, and evaluate contributions to our understanding of changes in Earth systems over geological time;

D2. investigate geological evidence of major changes that have occurred during Earth's history, and of the various processes that have contributed to these changes;

D3. demonstrate an understanding of how changes to Earth's surface have been recorded and preserved throughout geological time and how they contribute to our knowledge of Earth's history.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse the relationship between climate and geology, and, using geological records, assess the impact of long-term climate change on life on Earth [AI, C]

Sample issue: Geological records provide scientists with important evidence about climate change and changes in life on Earth. Not all scientists agree about the significance and meaning of geological evidence, however, and there is disagreement about the accuracy of some dating techniques.

Sample questions: What do changes in atmospheric conditions recorded throughout the geological record tell us about past and present environmental conditions? How have the patterns of ocean currents changed as a result of continental drift, and how has this affected Earth's climate? What environmental and evolutionary changes are seen from the Devonian period to the Carboniferous period?

D1.2 evaluate the significance of contributions, including Canadian contributions, to our understanding of geological time and of changes in Earth systems over time (e.g., the contributions of Raymond A. Price; the Canadian contribution to the development of Landsat) [AI, C]

Sample issue: Canadian geologist John Tuzo Wilson devised the idea of "hot spots" – magma that remains stationary under moving plates – to account for the formation of volcanic chains like the Hawaiian Islands. He also developed the concept of transform faults to explain phenomena like the San Andreas Fault. Explore the significance of these contributions to the study of plate tectonics.

Sample questions: What contributions have Canadian scientists made to the study of sediment and glacial records, and how have these contributions increased our understanding of long-term changes in Earth systems? What role have Canadians played in the development or use of technological applications such as Radarsat, and how have these applications contributed to our knowledge of Earth systems?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to Earth and its geological history, including, but not limited to: *Milankovitch cycles*, *era*, *epoch*, *period*, *parent isotope*, *hot spot*, *paleomagnetism*, and *index fossil* [C]

D2.2 use a research process to investigate the geological history of an area in Ontario (e.g., use a sequence diagram, geological maps showing main geological units or associated rock types, and/or surficial/bedrock geology maps to investigate the Oak Ridges Moraine or Niagara Escarpment) [IP, PR]

D2.3 investigate various types of preserved geological evidence of major changes that have taken place in Earth history (e.g., fossil evidence of mass extinctions, topographic evidence of past glaciations, evidence of plate movement in igneous rocks with magnetic reversals) [PR]

D2.4 produce a model or diagram to illustrate how geological time scales compare to human time scales (e.g., major events in Earth's geological history or the geological history of their region compared to major events in human history or students' own lifespans) [PR, C]

D2.5 produce diagrams to illustrate the development of various types of unconformities preserved in a sequence of strata (e.g., angular unconformity, disconformity, nonconformity) [PR, C]

D2.6 design and build a model to represent radioactive decay and the concept of half-life determination [IP, PR]

D2.7 investigate interactions over time between physical, chemical, and biological processes, and explain how they have affected environmental conditions throughout Earth's geological history (e.g., the impact of increasing amounts of atmospheric oxygen on stromatolites; the impact of increasing amounts of atmospheric carbon dioxide on global warming; the influence of plants on the water cycle, other life forms, the atmosphere, weathering, and erosion) [PR, AI, C]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 describe evidence for the evolution of life through the Proterozoic, Paleozoic, Mesozoic, and Cenozoic eras, using important groups of fossils that date from each era (e.g., stromatolites, trilobites, brachiopods, crinoids, fish, angiosperms, gymnosperms, dinosaurs, mammals)

D3.2 describe various kinds of evidence that life forms, climate, continental positions, and Earth's crust have changed over time (e.g., evidence of mass extinction, of past glaciations, of the existence of Pangaea and Gondwanaland)

D3.3 describe some processes by which fossils are produced and/or preserved (e.g., original preservation, carbonization, replacement, permineralization, mould and cast formations)

D3.4 compare and contrast relative and absolute dating principles and techniques as they apply to natural systems (e.g., the law of superposition; the law of cross-cutting relationships; varve counts; carbon-14 or uranium-lead dating)

D3.5 identify and describe 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 that it can be used to date (e.g., uranium-lead dating of rocks; carbon dating of organic materials)

D3.6 explain the influence of paradigm shifts (e.g., from uniformitarianism to catastrophism) in the development of geological thinking

D3.7 explain the different types of evidence used to determine the age of Earth (e.g., index fossils; evidence provided by radiometric dating of geological materials or lithostratigraphy) and how this evidence has influenced our understanding of the age of the planet

E. EARTH MATERIALS

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse technologies used to explore for and extract Earth materials, and assess the economic and environmental impact of the exploitation of such materials;

E2. investigate the properties of minerals and characteristics of rocks, including those in their local area;

E3. demonstrate an understanding of the properties of minerals and the formation and characteristics of rocks.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 assess the direct and indirect impact on local, provincial/regional, or national economies of the exploration for and extraction and refinement/processing of Earth materials (e.g., gold, uranium, sand, gravel, dimension stone, fossil fuels) [AI, C]

Sample issue: Diamonds are prized for industrial and personal uses. The demand contributes to the existence of illegal trade in "blood diamonds", in which stones mined in war zones are sold and the revenue is used to fund military action by insurgent groups. The protracted wars devastate local and national economies.

Sample questions: What are the effects on local economies of oil extraction in Alberta, transportation by pipeline through the Prairies, and refinement in Ontario? How does the economic benefit of manufacturing items using a mineral resource compare to the economic benefits for the communities that mine the resource? What is the impact on the economy of local Aboriginal communities of diamond mining on their lands?

E1.2 analyse technologies and techniques used to explore for and extract natural resources, and assess their actual or potential environmental repercussions [AI, C]

Sample issue: Mountaintop removal is a coal-mining technique proposed for use near the headwaters of the Flathead River in British Columbia. Mining companies favour the technique because the coal can be removed more cheaply than in conventional mining. However, the process devastates the local environment, causing erosion, loss of terrestrial and aquatic habitat, and air and water pollution.

Sample questions: Why has there been so much protest against the proposed Mackenzie Valley pipeline in the Canadian North? What mining techniques have the greatest and the least impact on local water systems? How are assessments of the permeability and porosity of rock structures used to determine the location of fossil fuels? What impact has the extraction of oil from the Alberta oil sands had on the local environment?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to Earth materials, including, but not limited to: *geothermal vents, porosity, permeability, cleavage, fracture, cementation, evaporite,* and *foliation* [C]

E2.2 investigate the properties of various Earth materials (e.g., density, conductivity, porosity; whether they are magnetic or radioactive), and explain how these properties affect how the materials are used and what technologies and techniques are used to explore for or extract them (e.g., radiometric instruments, electromagnetic or gravity surveys) [PR, AI, C]

E2.3 conduct a series of tests (e.g., hardness, streak, density) to identify and classify common minerals (e.g., quartz, calcite, potassium feldspar, plagioclase feldspar, muscovite, biotite, talc, graphite, hornblende) [PR, AI]

E2.4 investigate common igneous rocks (e.g., granite, obsidian, andesite, basalt, gabbro), using a hand lens, classify them on the basis of their texture (e.g., porphyritic, phaneritic, aphanitic) and composition (e.g., acid, intermediate, basic), and use this information to determine their origins (i.e., extrusive or intrusive) [PR, AI]

E2.5 investigate sedimentary rocks (e.g., conglomerate, breccia, sandstone, shale, limestone, dolostone, chert, gypsum, rock salt, coal), using a hand lens, classify them on the basis of their texture (e.g., coarse- or fine-grained, detrital) and composition (e.g., clastic, chemical, fossil inclusions), and use this information to determine their origin (e.g., clastic, chemical) [PR, AI]

E2.6 investigate metamorphic rocks (e.g., slate, phyllite, schist, gneiss, quartzite, marble), using a hand lens, and classify them on the basis of their characteristics (e.g., foliation, crystallinity) in order to identify their parent rock and the temperature, pressure, and chemical conditions at their formation [PR, AI]

E2.7 investigate a geological setting in their local area (e.g., a river/stream bed or lakeshore; a rock outcrop), and identify and classify rock samples collected from that area [PR, AI]

E2.8 plan and conduct an inquiry to investigate the factors that determine the size and form of mineral crystals (e.g., the temperature of the solution, the type of salt, the level of saturation, the temperature of slides containing melted salol) [IP, PR]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 identify the physical and chemical properties of selected minerals, and describe the tests used to determine these properties

E3.2 describe the formation (i.e., intrusive or extrusive) and identify the distinguishing characteristics of igneous rocks (e.g., composition and eruption type; mineralogical content indicating the type of volcano in which a rock was formed)

E3.3 describe the formation of clastic and chemical sediments, and the characteristics of the corresponding sedimentary rocks (e.g., shape and size of particles, nature of their deposition)

E3.4 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; regional or contact metamorphism)

E3.5 describe the role of Earth materials in the safe disposal of industrial and urban waste and toxic materials (e.g., the low permeability of clays makes them suitable material for barriers in waste disposal sites)

F. GEOLOGICAL PROCESSES

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse technological developments that have increased our knowledge of geological processes and structures, and how this knowledge assists in monitoring and managing these processes and structures;

F2. 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 quantified;

F3. demonstrate an understanding of the processes at work within Earth and on its surface, and the role of these processes in shaping Earth's surface.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 evaluate the accuracy and reliability of technological methods of monitoring and predicting earthquakes, tsunamis, and volcanic eruptions [AI, C]

Sample issue: In the past, seismometers used a pendulum attached to a stylus to detect anomalies in the movement of Earth's surface. Modern seismometers use electronic sensors and amplifiers. These seismographic systems are located worldwide, allowing scientists to predict the timing and location of earthquakes with increased accuracy.

Sample questions: What new technologies have been developed to monitor tsunamis since the devastating tsunami in the Indian Ocean in December 2004? How accurately can scientists predict major volcanic eruptions? How accurate are various technologies used to predict earthquakes?

F1.2 analyse developments in technology (e.g., sonar, seismology, magnetometers) or Earth science endeavours (e.g., Lithoprobe, Geosat, Ocean Drilling Program) that have contributed to our understanding of Earth's interior, crust, and surface [AI, C]

Sample issue: Magnetometers have developed from bulky land-based machines to sensitive, satellite-mounted devices that survey vast areas. Magnetometers provide information on underground rock formations, on the location of resources such as fossil fuels and iron ore, on anomalies in Earth's crust, and on the movement of land masses.

Sample questions: How can the global positioning system (GPS) be used to gather information on plate movements? What is the Lithoprobe project, and how has it enhanced our knowledge of Earth's interior? How are seismographs used to detect water below Earth's surface?

F1.3 analyse the relationship between human activities and various geological structures and processes (e.g., the relationship between the location of deposits and the extraction/use of resources; the relationship between urban development and/or building codes and the probability of earthquakes or volcanic activity), and propose ways in which the relationships can be effectively or sustainably managed [AI, C]

Sample issue: Volcanic eruptions can be destructive and deadly. However, because volcanic soil is rich and fertile, it is valued as farmland, and farms, towns, and even cities have developed near volcanoes. Constant monitoring of volcanic activity and development of evacuation plans are necessary to reduce the risk for human habitations near a volcano.

Sample questions: What impact do stream erosion and alluvial deposits have on agriculture along a river? What are some ways in which humans can exploit mineral resources without depleting them or harming the environment? What negative effects can construction projects have on surface water or groundwater systems? How can these effects be reduced?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to geological processes, including, but not limited to: *shear forces, compression forces, liquifaction, Benioff zone, aquifer, internal plastic flow, basal slip, mid-oceanic ridge, bedding, cross-cutting, isostasy,* and *lithification* [C]

F2.2 investigate the difference between weathering and erosion (e.g., weathering occurs when the edge of a riverbank disintegrates from the force of the water; erosion occurs when the water transports the soil downstream), and construct models of the processes of physical, chemical, and biological weathering (e.g., tap water dripping on a bar of soap; vinegar dripping on a marble chip; dried beans soaking in a sealed plastic jar) [PR]

F2.3 produce a model showing simple sedimentary sequences (e.g., successive layering, sorted sequences), using block diagrams or three-dimensional models (e.g., layering as sand settles in an aquarium) [PR, C]

F2.4 investigate, through laboratory inquiry or computer simulation, the main types of seismic waves, and produce a model (e.g., using 3D block diagrams or springs and ropes) to illustrate for each the nature of its propagation, the transfer of energy, and its movement through rocks [PR, C]

F2.5 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) [AI]

F2.6 produce a scale model (e.g., a 3D block diagram) of the interior of Earth, differentiating between the layers and their characteristics (e.g., label cross-sections with the dimensions of the crust, mantle, and inner and outer core, and add travel-time curves for various seismic waves to provide data on the characteristics of the individual layers) [PR, C]

F2.7 design and test models that show the types (i.e., falls, slides, or flows) and causes (e.g., effect of gravity [angle of repose], water content, earthquakes) of mass wasting [IP, PR, AI]

F2.8 analyse information from a plan view (e.g., topographic map, air photo, geologic map) and sectional view (e.g., cross section, block diagram) in order to deduce the geologic history of an area [AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 describe the types of boundaries (convergent, divergent, transform) between lithospheric plates, and explain the types of internal Earth processes occurring at each (e.g., subduction, divergence, convergence, hot spot activity, folding, faulting)

F3.2 describe the characteristics of the main types of seismic waves (i.e., P- and S-waves; R- and L-waves), and explain the different modes of travel, travel times, and types of motion associated with each

F3.3 compare qualitative and quantitative methods used to measure earthquake intensity and magnitude (e.g., the Mercalli Scale, the Richter Scale)

F3.4 explain how different erosional processes contribute to changing landscapes (e.g., channel erosion, mass-wasting events)

F3.5 identify and describe types of sediment transport (e.g., water, wind, glacial) and the types of load (i.e., dissolved load, suspended load, bed load) as sediment is moved by each type of transport

F3.6 describe the landforms produced by water, wind, or ice erosion

F3.7 describe the sedimentary structures formed by wind, water, or ice deposition

F3.8 identify major areas of tectonic activity in the world by plotting the location of major recorded earthquakes and active volcanoes on a map, and distinguish the areas by type of tectonic activity (e.g., Japan – convergent boundary; Iceland – divergent boundary; California – transform boundary)

F3.9 explain the processes of continuous recycling of major rock types (i.e., the rock cycle) throughout Earth history

ENVIRONMENTAL SCIENCE

Environmental Science, Grade 11

University/College Preparation **SVN3M**

This course provides students with the fundamental knowledge of and skills relating to environmental science that will help them succeed in life after secondary school. Students will explore a range of topics, including the role of science in addressing contemporary environmental challenges; the impact of the environment on human health; sustainable agriculture and forestry; the reduction and management of waste; and the conservation of energy. Students will increase their scientific and environmental literacy and examine the interrelationships between science, the environment, and society in a variety of areas.

Prerequisite: Grade 10 Science, Applied or Academic

Big Ideas

Scientific Solutions to Contemporary Environmental Challenges

- Current environmental issues are complex, and may involve conflicting interests or ideas.
- Scientific knowledge enables people to make informed decisions about effective ways to address environmental challenges.

Human Health and the Environment

- Environmental factors can have negative effects on human health.
- It is possible to minimize some of the negative health effects of environmental factors by making informed lifestyle choices and taking other precautions.

Sustainable Agriculture and Forestry

- Modern agricultural and forestry practices can have positive and negative consequences for the economy, human health, and the sustainability of ecosystems, both local and global.

Reducing and Managing Waste

- Well-thought-out waste management plans help to sustain ecosystems, locally and globally.
- By making informed choices, consumers can reduce the amount or alter the nature of the waste they produce.

Conservation of Energy

- The impact of energy production and consumption on environmental sustainability depends on which resources and energy production methods are used.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Scientific Solutions to Contemporary Environmental Challenges	Human Health and the Environment	Sustainable Agriculture and Forestry	Reducing and Managing Waste	Conservation of Energy
Matter	✓	✓	✓	✓	
Energy	✓	✓	✓	✓	✓
Systems and Interactions	✓	✓		✓	
Structure and Function		✓		✓	✓
Sustainability and Stewardship	✓	✓	✓	✓	✓
Change and Continuity	✓				

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., probes, moisture meters, rain gauges), and materials (e.g., water-sampling kits, soil-testing kits), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., organic chemist, landscaper, conservationist, air quality technician, personal support worker, environmental lawyer) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Pierre Dansereau, Margaret Newton, Johan F. Dormaar, Sheila Watt-Cloutier, Severn Cullis-Suzuki), to the fields under study

B. SCIENTIFIC SOLUTIONS TO CONTEMPORARY ENVIRONMENTAL CHALLENGES

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse social and economic issues related to an environmental challenge, and how societal needs influence scientific endeavours related to the environment;

B2. investigate a range of perspectives that have contributed to scientific knowledge about the environment, and how scientific knowledge and procedures are applied to address contemporary environmental problems;

B3. demonstrate an understanding of major contemporary environmental challenges and how we acquire knowledge about them.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse, on the basis of research, social and economic issues related to a particular environmental challenge (e.g., overfishing, deforestation, acid rain, melting of the polar ice cap) and to efforts to address it [IP, PR, AI, C]

Sample issue: Greenhouse gas emissions from motor vehicles are a major contributor to global warming. The use of ethanol and other biofuels in motor vehicles reduces these emissions. However, diverting crops from food production to fuel production can increase prices and decrease the supply of food.

Sample questions: What are some of the social and economic challenges associated with cleaning up and conserving fresh water supplies? What are some alternative energy sources? What social and economic challenges are associated with their development? In what ways can consuming locally grown foods help the local economy, society, and the environment?

B1.2 analyse ways in which societal needs or demands have influenced scientific endeavours related to the environment (e.g., the development of drought- and pest-resistant crops to address the rising global need for food; research into alternative energy sources in response to demands to address the impact on climate change of burning fossil fuels) [AI, C]

Sample issue: Because of unstable oil prices and the environmental damage caused by motor vehicle emissions, many consumers have been demanding more environmentally friendly vehicles. As a result, car companies are devoting greater resources towards the development of more fuel-efficient engines, hybrid vehicles, and cars powered by electricity or other types of energy.

Sample questions: How and why do demands by environmentally conscious consumers affect the types of products developed by corporations? What impact have the energy needs of remote communities had on innovations in the development of off-grid energy sources? What types of products have been developed in response to the health threats resulting from ozone depletion?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to the application of scientific knowledge and procedures to environmental issues, including, but not limited to: *fact, inference, paradigm, objectivity,* and *causality* [C]

B2.2 plan and conduct a laboratory inquiry to test a scientific procedure used to address a contemporary environmental problem (e.g., an oil spill, acid precipitation) [IP, PR, AI]

B2.3 investigate, through research or using case studies or computer simulation, how scientific knowledge and procedures are applied to address a particular contemporary environmental issue (e.g., scientific data on the needs and habits of endangered species are used to develop plans to protect threatened species; life-cycle assessments are conducted to determine the total environmental impact of a consumer product) [PR, AI]

B2.4 use a research process to investigate how evidence, theories, and paradigms reflecting a range of perspectives have contributed to our scientific knowledge about the environment (e.g., with respect to debates about climate change; regarding the relationship between the cod moratorium and seal populations in Atlantic Canada), and communicate their findings [IP, PR, AI, C]

B2.5 use a research process to locate a media report on a contemporary environmental issue (e.g., climate change, melting of the polar ice cap, deforestation), summarize its arguments, and assess their validity from a scientific perspective [IP, PR, AI, C]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 identify some major contemporary environmental challenges (e.g., global warming, acid precipitation), and explain their causes (e.g., deforestation, carbon and sulfur emissions) and effects (e.g., desertification, the creation of environmental refugees, the destruction of aquatic and terrestrial habitats)

B3.2 describe how scientists use a variety of processes (e.g., environmental impact assessments, environmental scans) to solve problems and answer questions related to the environment

B3.3 explain how new evidence affects scientific knowledge about the environment and leads to modifications of theory and/or shifts in paradigms (e.g., the impact of evidence of the effects of carbon dioxide emissions on theories of global warming)

B3.4 explain how an environmental challenge has led to advances in science or technology (e.g., scrubbers on smokestacks to decrease sulfur dioxide emissions, hybrid cars)

B3.5 describe a variety of human activities that have led to environmental problems (e.g., burning fossil fuels for transportation or power generation; waste disposal) and/or contributed to their solution (e.g., the development of renewable sources of energy; programs to reduce, reuse, and recycle)

C. HUMAN HEALTH AND THE ENVIRONMENT

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse initiatives, both governmental and non-governmental, that are intended to reduce the impact of environmental factors on human health;

C2. investigate environmental factors that can affect human health, and analyse related data;

C3. demonstrate an understanding of various environmental factors that can affect human health, and explain how the impact of these factors can be reduced.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse grassroots initiatives that are intended to reduce the impact of environmental factors on human health (e.g., community cleanup of local aquatic or terrestrial environments; class action lawsuits against major polluters) [AI, C]

Sample issue: People from the Grassy Narrows Reserve in Northern Ontario were experiencing chronic health problems. They commissioned a study, which found that many animals and fish that were part of a traditional diet were contaminated with mercury and heavy metals. Guidelines were proposed to limit consumption of the affected animals, and thereby improve people's health.

Sample questions: Are there any grassroots groups in your community concerned with the state of the environment and its impact on human health? What types of actions do they take? What action has been taken by the Bulkley Valley and Lakes District Airshed Management Society to help reduce the impact of particulate matter in air on the health of local people? What is the Yellow Fish Road program, and how does it try to reduce the number of contaminants in local water sources?

C1.2 evaluate the effectiveness of government initiatives that are intended to reduce the impact of environmental factors on human health (e.g., Ontario Ministry of the Environment smog advisories; provincial laws regulating drinking water; WHMIS regulations on hazardous material) [AI, C]

Sample issue: To protect the health of people who live on the street, the City of Toronto issues heat and cold alerts, opening cooling centres or heated shelters where people can escape extreme weather conditions. However, not everyone is aware of these services, and there are not always enough spaces to meet needs.

Sample questions: Why does the Ontario Ministry of the Environment issue smog advisories? Why are there concerns about the water quality in many First Nations communities in Canada? Why did the water treatment plant in Kashechewan, in Northern Ontario, fail to protect the community from contaminated water?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to human health and the environment, including, but not limited to: *contaminants, heavy metals, air pollution,* and *pesticide* [C]

C2.2 analyse longitudinal data to determine the impact of various environmental factors that affect human health (e.g., air temperature, atmospheric greenhouse gases, contaminants in drinking water) [AI]

C2.3 investigate, through laboratory inquiry or field study, water samples from natural and disturbed environments (e.g., tap water; pond, river, or lake water from disturbed and undisturbed areas; water from an outdoor pool), and analyse the resulting data [PR, AI]

C2.4 analyse, on the basis of a laboratory inquiry, computer simulation, or field study, particulate matter in air (e.g., an air sample from an exhaust pipe or air vent, particles in a filter that cigarette smoke has passed through, particles caught on sticky paper set up in an open area) [PR, AI]

C2.5 investigate health standards for buildings and methods to retrofit or otherwise improve structures to reduce their negative impact on human health (e.g., the use of materials that do not contain volatile organic compounds, the use of biological air and water filters), and communicate their findings [PR, C]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 identify the main pollutants and environmental contaminants that can affect human health (e.g., air pollutants such as sulfur dioxide, nitrous oxide, and particulates; noise pollution; heavy metals such as lead and mercury; DDT; PCBs; mould; volatile organic compounds such as acetone and chlorinated solvents)

C3.2 describe the effects of a variety of environmental factors on human health (e.g., air pollutants are associated with disorders such as asthma; consumption of fish products from contaminated water may lead to increased levels of heavy metals in the human body; the thinning of the ozone layer may lead to increased incidence of skin cancer; noise pollution may impair hearing)

C3.3 describe ways in which a variety of environmental contaminants (e.g., volatile organic compounds in paints, carpets, and cleaning products; mercury in fish; E. coli in the water at public beaches) can enter the human body (e.g., inhalation, ingestion, absorption)

C3.4 describe measures that can reduce exposure to environmental contaminants (e.g., wearing protective clothing or sunscreen, or remaining indoors during peak UV hours, to prevent exposure to ultraviolet rays; avoiding the use of paints, solvents, and cleaning agents that contain volatile organic compounds)

C3.5 identify a variety of populations who are particularly vulnerable to the effects of environmental factors, and explain why these populations are vulnerable (e.g., seniors are vulnerable to extreme temperatures because the ability to regulate body temperature diminishes as people age; Inuit who follow a traditional diet are vulnerable to contaminants that accumulate in the fatty tissue of sea mammals because these animals are their main food source)

D. SUSTAINABLE AGRICULTURE AND FORESTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. evaluate the impact of agricultural and forestry practices on human health, the economy, and the environment;

D2. investigate conditions necessary for plant growth, including the soil components most suitable for various species, and various environmentally sustainable methods that can be used to promote growth;

D3. demonstrate an understanding of conditions required for plant growth and of a variety of environmentally sustainable practices that can be used to promote growth.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 evaluate, on the basis of research, a variety of agricultural and forestry practices (e.g., companion planting, biological pest control, the use of genetically modified seed, forest fire control) with respect to their impact on the economy and the environment (e.g., the use of nematodes eliminates crop damage from grubs, thus contributing to better harvests, while reducing the use of toxic chemical pesticides; under some circumstances, forest thinning can help prevent or reduce the seriousness of forest fire, and its economic and environmental consequences) [IP, PR, AI, C]

Sample issue: The recycling of animal waste as fertilizer is economical and is generally considered an environmentally sustainable practice. However, care must be taken that the manure does not run off into water sources, as it can contaminate them with E. coli and other bacteria.

Sample questions: What are the economic and environmental pros and cons of growing crops that are genetically modified to be herbicide resistant? Why is organic produce more expensive than conventionally grown produce? What are the economic advantages of monoculture, both on farms and in forestry operations? How can monocultural practices lead to environmental degradation? What types of forestry practices can be implemented to maintain features of old-growth ecosystems while harvesting trees?

D1.2 evaluate, on the basis of research, the impact, including the long-term impact, of agricultural and forestry practices on human health (e.g., the use of chemical fertilizers and pesticides; the use of growth hormones and antibiotics in livestock; the use of feed containing animal by-products; the clear-cutting of forests) [IP, PR, AI, C]

Sample issue: The toxins in pesticides can accumulate in the human body over the years. Although the immediate effects of exposure to pesticide may be unnoticeable, the chemicals build up in body fat and organs and can lead to a variety of cancers.

Sample questions: What was the source of contamination of well water in Walkerton, Ontario, in 2000? What are the immediate and long-term health effects of exposure to E. coli? What is known about the long-term effects of consuming genetically modified food? What impact could the spraying of forest canopies to prevent gypsy moth infestations have on human health?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to sustainable agriculture and forestry, including, but not limited to: *bioremediation, crop rotation, companion planting, organic product, humus, compost, mulch, silviculture,* and *naturalization* [C]

D2.2 test samples of a variety of types of soil (e.g., clay, loam, commercial potting soil) to determine their nutrients and composition (e.g., pH; the percentage of nitrogen, phosphorus, and potassium; porosity; moisture) [PR, AI]

D2.3 use an inquiry process to investigate the nutrients in and composition of a variety of compost samples (e.g., nutrients such as nitrogen, phosphorous, potassium; composition with respect to pH, porosity), and analyse the findings to determine appropriate uses for each sample [IP, PR, AI]

D2.4 prepare a soil mixture (e.g., using compost, manure, vermiculite, black earth, top soil, peat moss, loam, and/or sand) for a selected plant species, based on analysis of the criteria for optimal growth for that species (e.g., cactus, tomato plants, wheat, jack pine) [PR, AI]

D2.5 use a research process to investigate environmentally sustainable methods of managing and maintaining healthy and productive agricultural zones and forests (e.g., companion planting, crop rotation, selective tree-harvesting, planting a diverse canopy) [IP, PR]

D2.6 design a landscaping project for their local area (e.g., a rooftop garden, a plot in a community garden, a riparian restoration), taking into account local conditions (e.g., zone hardiness, soil composition, amount of sunlight and rainfall), and propose a course of action to ensure the sustainability of the project and its healthy interaction with the surrounding environment (e.g., companion gardening, the use of compost to fertilize the soil, the use of native plants, the inclusion of plants that attract birds or butterflies) [IP, PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the basic principles of various agricultural and forestry practices (e.g., Integrated Pest Management), and identify regulations and regulatory bodies associated with these practices (e.g., Health Canada's Pest Management Regulatory Agency [PMRA], the Pest Control Products Act)

D3.2 describe the basic requirements for plant growth (e.g., growing medium, light, moisture, nutrients)

D3.3 describe the soil components (e.g., pH, moisture, the percentage of humus, porosity with respect to water and air) needed by a variety of plants for optimal growth

D3.4 explain different ecologically sound practices for improving and maintaining soil structure and fertility (e.g., crop rotation, fallowing, adding compost or manure, inter-seeding grains and legumes, mulching, tree harvesting using a shelterwood system)

D3.5 explain agricultural techniques and forestry practices that aim to maintain both biodiversity and long-term productivity (e.g., growing a variety of species, inter-planting crops, planting native and heritage varietals instead of hybrids or transgenic species, saving seeds, maintaining some older trees and snags for animal habitat)

D3.6 describe sustainable water-management practices in agricultural and forestry settings (e.g., regulating the frequency of watering, planting species suited to local precipitation levels, limiting run-off and erosion)

E. REDUCING AND MANAGING WASTE

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse economic, political, and environmental considerations affecting waste management strategies;

E2. investigate the effectiveness of various waste management practices;

E3. demonstrate an understanding of the nature and types of waste and strategies for its management.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse, on the basis of research, the impact of economic and political considerations on the development of waste management practices or strategies (e.g., incineration of hazardous waste; biological filtration and reuse of greywater; user fees for garbage disposal; vermicomposting) [IP, PR, AI, C]

Sample issue: The use of landfill sites has been a long-time strategy for disposal of garbage. As local sites fill up, some municipalities are shipping their garbage to distant sites. This strategy is often politically unpopular and, with high fuel prices, is increasingly expensive, so local politicians are under pressure to implement new strategies.

Sample questions: What are the costs of recycling compared to the costs of using landfill sites or incinerating garbage? Why is garbage incineration a controversial political issue? Why do municipal recycling programs recycle only a limited number of items?

E1.2 evaluate the short- and long-term impact on the environment of a specific type of waste (e.g., waste products from animal farming; plastic shopping bags; tailings from mines) [AI, C]

Sample issue: Non-rechargeable batteries can be convenient, but their disposal presents problems. Batteries contain heavy metals and corrosive substances that can contaminate landfill sites and leach into surrounding soil or water. Ontario municipalities designate batteries as hazardous waste, yet some people continue to throw them in the garbage.

Sample questions: What impact do disposable diapers have on the environment? What effects does the dumping of solid waste into lakes, rivers, or oceans have on aquatic life? How long does it take polystyrene, widely used to make food and drink containers, to break down? What environmental challenges are associated with nuclear waste?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to waste management, including, but not limited to: *solid, liquid, and gaseous waste; toxic waste; heavy metal; chlorinated hydrocarbons;* and *polychlorinated biphenyls (PCBs)* [C]

E2.2 plan and conduct an inquiry in a micro-environment to treat a solid, liquid, or gaseous waste (e.g., reduce the acidity in a closed bog system in an aquarium; use a vermicomposter to recycle solid organic matter) [IP, PR]

E2.3 use a research process to investigate the waste generated throughout the life cycle of a product (e.g., the waste associated with all the materials and energy that go into the development and disposal of a computer or a running shoe) [IP, PR]

E2.4 plan and conduct a waste audit within their school, and propose a plan of action for waste reduction based on their findings (e.g., review the school's policy regarding paper and plastic recycling, monitor actual practices, and propose strategies to improve them) [IP, PR, AI, C]

E2.5 investigate a local, regional, national, or global waste management practice (e.g., local practices such as recycling or charging for residential and/or commercial garbage bags; shipping garbage to landfill sites in another region; disposal of nuclear waste; dumping raw sewage into rivers, lakes, oceans), and communicate their findings [PR, C]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe different categories of waste (e.g., biodegradable, recyclable, toxic, organic, inorganic)

E3.2 explain some current waste remediation practices used with substances or products that are not environmentally friendly (e.g., "Toxic Taxi" for pick-up of household hazardous waste; the recycling of plastic to make furniture and "lumber")

E3.3 describe the scientific principles involved in processing solid, liquid, and gaseous waste (e.g., combustion, decomposition, pyrolysis)

E3.4 explain common strategies and technologies used in the collection and storage of waste (e.g., strategies such as recycling, composting, dumping in landfill sites; technologies such as compacters, enzyme digesters, flocculation tanks)

E3.5 explain how scientific knowledge and technological processes have been applied in the development of environmentally sound waste management strategies (e.g., accelerated waste aeration, bioremediation)

F. CONSERVATION OF ENERGY

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. assess the impact on society and the environment of the use of various renewable and non-renewable energy sources, and propose a plan to reduce energy consumption;

F2. investigate various methods of conserving energy and improving energy efficiency;

F3. demonstrate an understanding of energy production, consumption, and conservation with respect to a variety of renewable and non-renewable sources.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 evaluate the impact on the environment of renewable and non-renewable energy sources, and propose an environmentally friendly solution to reduce non-renewable energy consumption (e.g., a plan for broader use of hybrid cars or solar panels) [AI, C]

Sample issue: In some remote areas that are off the electrical grid, generators that run on fossil fuels are used to generate electricity. However, these devices are inefficient, and they produce carbon dioxide, which contributes to global warming, and noise pollution.

Sample questions: What impact can hydroelectric dams and generating stations have on the local environment? What effects do coal mining and the use of coal-burning power plants have on the local, regional, and global environment? How can the use of ethanol reduce the amount of petroleum needed to run cars?

F1.2 assess the costs and benefits to society of the use of renewable and non-renewable energy sources, using a variety of criteria (e.g., associated health concerns, reliability, ability to meet demand, start-up and production costs) [AI, C]

Sample issue: The extraction, processing, and burning of fossil fuels damage the environment. However, some fossil fuels, such as coal, are plentiful and therefore a reliable source of energy. Some alternative energy sources, such as wind and solar power, are less reliable, and their unit costs are much higher.

Sample questions: How do the costs of coal and geothermal power compare? Do these costs change when environmental costs and benefits of the two sources are factored in? What are the health concerns associated with nuclear power? Why are wind and solar power less reliable than fossil fuel sources? How could that change?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to energy conservation, including, but not limited to: *renewable resource, non-renewable resource,* and *R-value*

F2.2 investigate energy consumption and costs in their household over a given period of time, and suggest ways in which their household could conserve energy [PR, AI, C]

F2.3 plan and conduct an energy audit of a home or business, and propose ways to improve its energy efficiency [IP, PR, AI, C]

F2.4 design and construct a working model of a device that uses an alternative energy source (e.g., a wind generator, a solar-powered car, a "fan boat") [IP, PR]

F2.5 plan and conduct an inquiry to evaluate the effectiveness of various insulation materials and/or techniques (e.g., straw, foam, fibreglass, blown cellulose) [IP, PR, AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 explain the historical significance of a variety of energy sources (e.g., whale oil, coal), and describe their long-term impact on the environment

F3.2 describe the characteristics of a sustainable energy system (e.g., equitable access to the source, long-term availability, limited environmental impact)

F3.3 explain the basic principles and characteristics of various types of renewable (e.g., tidal, geothermal, solar, wind) and non-renewable (e.g., coal, oil, gas) energy production and their impact on the environment

F3.4 describe methods of energy production and conservation intended to reduce greenhouse gas emissions (e.g., energy production methods at the Prince Edward Island Wind-Hydrogen Village; charging higher prices for energy used during peak hours)

F3.5 describe technological advances aimed at reducing energy consumption (e.g., programmable thermostats, improved R-value in insulation, compact fluorescent light bulbs, rechargeable batteries, "smart meters")

Environmental Science, Grade 11

Workplace Preparation **SVN3E**

This course provides students with the fundamental knowledge of and skills relating to environmental science that will help them succeed in work and life after secondary school. Students will explore a range of topics, including the impact of human activities on the environment; human health and the environment; energy conservation; resource science and management; and safety and environmental responsibility in the workplace. Emphasis is placed on relevant, practical applications and current topics in environmental science, with attention to the refinement of students' literacy and mathematical literacy skills as well as the development of their scientific and environmental literacy.

Prerequisite: Science, Grade 9, Academic or Applied, or a Grade 9 or 10 locally developed compulsory credit (LDCC) course in science

Big Ideas

Human Impact on the Environment
- The biotic elements of an ecosystem include humans.
- Abiotic and biotic factors interact within an ecosystem.
- People have positive and negative effects on the environment, both locally and globally.

Human Health and the Environment
- Environmental factors can have negative effects on human health.
- It is possible to minimize some negative health effects associated with environmental factors by making wise lifestyle choices and taking other precautions.

Energy Conservation
- The impact of energy production and consumption on environmental sustainability depends on which resources and energy production methods are used.

Natural Resource Science and Management
- Biodiversity is a measure of the health and sustainability of an ecosystem.
- Careful resource management planning is necessary to sustain ecosystems.

The Safe and Environmentally Responsible Workplace
- Workplace safety is the responsibility of both employees and employers.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Human Impact on the Environment	Human Health and the Environment	Energy Conservation	Natural Resource Science and Management	The Safe and Environmentally Responsible Workplace
Matter	✓	✓		✓	✓
Energy		✓	✓		
Systems and Interactions	✓				✓
Structure and Function					
Sustainability and Stewardship	✓	✓	✓	✓	✓
Change and Continuity	✓			✓	

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., pH probes, plant tags, soil markers) and materials (e.g., botanical keys, personal protection devices, soil test kits), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources (e.g., Material Safety Data Sheets, appliance manuals, hydro bills, the Live Safe! Work Smart! website) that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, graphic organizers, simulations, models, workplace labels)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., hydro meter reader, hospitality employee, waste management operator, custodian) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Mark Schacter, Sheila Watt-Cloutier, Marlo Reynolds, J. Ross MacKay, Linda Duncan), to the fields under study

B. HUMAN IMPACT ON THE ENVIRONMENT

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse selected current environmental problems in terms of the role human activities have played in creating or perpetuating them, and propose possible solutions to one such problem;

B2. investigate air, soil, and water quality in natural and disturbed environments, using appropriate technology;

B3. demonstrate an understanding of some of the ways in which human activities affect the environment and how the impact of those activities is measured and monitored.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 propose possible solutions, on the basis of research, to a current practical environmental problem that is caused, directly or indirectly, by human activities [IP, PR, AI, C]

Sample issue: Car emissions contribute to smog as well as global warming. Road tolls and increased use of public transit to cut down on the number of cars on the road, and the implementation and enforcement of idling by-laws, could significantly cut these emissions.

Sample questions: How can various kinds of chemical spills in local ecosystems (e.g., fields, rivers, streams) be cleaned up? In what ways does improper sewage treatment or agricultural run-off threaten local water supplies, and how can these dangers be addressed or averted? What can be done to minimize the effect of an invasive species (e.g., purple loosestrife) on a native species (e.g., milkweed)?

B1.2 analyse the risks and benefits to the environment of human recreational activities and the leisure industry [AI, C]

Sample issue: Ecotourism attempts to reduce the waste and environmental damage associated with mass tourism. Although responsible ecotourism seeks to conserve local ecosystems through sustainable practices, and can, for example, help reduce deforestation and animal poaching rates, any human intrusion can damage fragile ecosystems.

Sample questions: What are the risks to the environment of herbicide use and water consumption on golf courses? What are some of the risks and benefits to the environment of landscaping? In what ways can hunters and fishers damage the environment? In what ways can they contribute to its sustainability? What rules are needed to ensure that visitors to a protected area do not harm that ecosystem?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology relating to the environmental impact of human activity, including, but not limited to: *carbon footprint, carbon neutral, biodegradable, biodiversity, carrying capacity, sustainability,* and *invasive and native species* [C]

B2.2 plan and conduct an inquiry, using appropriate technology, to compare soil quality in natural and disturbed environments (e.g., compare the phosphorous content, pH, organic matter content, water content, water-holding capacity, nutrient content, porosity, and/or bulk density of soil from a forest or meadow and soil from a garden or farmer's field that has been treated with chemical fertilizer) [IP, PR, AI]

B2.3 plan and conduct an inquiry, using appropriate technology, to compare water quality in natural and disturbed environments (e.g., compare the pH, ion content, temperature, dissolved oxygen content, hardness, turbidity, biological oxygen demand [BOD], and/or fecal coliform of tap water, water from a pond or stream, and water from a drainage ditch) [IP, PR, AI]

B2.4 analyse and interpret data on particulate matter in air samples from several different regions of Canada, using prepared data from a variety of sources (e.g., the Ontario Ministry of the Environment – Air Quality Ontario, Environment Canada) [AI]

B2.5 plan and conduct a waste audit of their home or school [IP, PR]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 identify the basic components of soil, water, and air, and describe some of the effects of human activity on soil, water, and air quality (e.g., the effects of industrial or vehicle emissions on air quality; of chemical spills on soil quality; of chlorination on water quality)

B3.2 explain the concept of the cycling of substances in ecosystems (e.g., fertilizers made from biosolids leach into ground water or run off into rivers and streams, where the chemicals are absorbed by aquatic life, which is in turn consumed by humans)

B3.3 explain common methods of sampling soil, water, and air for analysis (e.g., soil core sampling, depth integrated sampling, stack sampling systems) and of monitoring soil, water, and air quality over time

B3.4 explain the concept of a "carbon footprint" and how it is used to measure the impact on the environment of a range of human activities

B3.5 explain the effects of human activity on an aquatic or terrestrial ecosystem (e.g., the impact of fertilizer run-off, acid precipitation, or an oil spill on an aquatic ecosystem)

B3.6 explain how human activities (e.g., agriculture, travel, the purchase of exotic pets, importing and exporting, releasing domesticated fish into fresh water environments, the use of live bait) have led to the introduction of invasive species, and why it is important to measure and monitor the impact of invasive species on native species

C. HUMAN HEALTH AND THE ENVIRONMENT

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse the effects on human health of environmental contaminants and a significant environmental phenomenon;

C2. investigate how different environmental factors can affect people's health and their lifestyle choices;

C3. demonstrate an understanding of the ways in which environmental factors can affect human health and how their impact can be reduced.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 assess, on the basis of research, the effects on human health of a significant environmental phenomenon (e.g., the ice storm of 1998 in central Canada, the European heatwave of 2003), and communicate their findings [IP, PR, AI, C]

Sample issue: In August 2005, Hurricane Katrina destroyed the levees surrounding New Orleans. Hundreds of people were drowned in the resulting floods. Many survivors contracted skin and gastro-intestinal diseases from contaminated water.

Sample questions: What impact did the 2003 drought in the Okanagan Valley have on the health and well-being of local populations? How did the 2003 tsunami in the Indian Ocean affect the health of people in that region?

C1.2 analyse how environmental contaminants can affect the health of different populations in Canada (e.g., mercury contamination in streams and rivers in Northern Ontario where Aboriginal people fish, toxins in Arctic sea mammals hunted by Inuit, smog in large cities) [AI, C]

Sample issue: When the U.S. government abandoned its Cold War military bases in the Canadian North, it left behind a variety of contaminants, including large amounts of polychlorinated biphenyls (PCBs). Exposure to these chemicals can affect the nervous system and the immune system and can cause cancer.

Sample questions: How does the use of biosolids as fertilizer on Canadian farms affect the health of local populations? What short- and long-term health problems can be traced to the chemicals in the tar ponds in Sydney, Nova Scotia?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate vocabulary related to human health and the environment, including, but not limited to: *smog*, *environmental contaminants*, *pathogens*, *inhalation*, *ingestion*, and *absorption* [C]

C2.2 investigate, using a research process, and report on an environmental factor that can have an impact on human health (e.g., smog, ultraviolet [UV] rays, bacteria, pesticide residue), and explain how their personal lifestyle choices can affect its impact (e.g., avoiding strenuous physical activity on days when there is a smog alert can reduce the severity of respiratory ailments; lying on the beach without sunscreen or sun protective clothing during peak UV hours can increase the risk of skin cancer) [IP, PR, AI, C]

C2.3 investigate the characteristics of a personal protective device or substance (e.g., sunscreen, mosquito repellent, respiratory mask, sun protective clothing) and whether the device or substance is effective in protecting a person from an environmental factor that can affect human health [PR, AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 describe common environmental factors, including pollution and environmental contaminants (e.g., air, noise, soil, and water pollution; UV rays; heat; heavy metals; workplace chemicals; pathogens), and explain how they can affect human health

C3.2 describe various ways in which environmental contaminants can enter the human body (e.g., inhalation, ingestion, absorption)

C3.3 explain how the human body can react to exposure to a variety of environmental factors (e.g., rashes, asthma, mercury poisoning, hearing loss, diseases such as malaria and cancer)

C3.4 describe medical and non-medical ways to protect oneself from the effects of harmful environmental factors (e.g., vaccination or medication, washing of fruits and vegetables, use of sunscreen or insect repellent, use of personal protective devices)

C3.5 describe good personal hygiene and household cleanliness practices that reduce health risks resulting from environmental contaminants (e.g., thorough hand washing, use of air filters, reduced use of household chemicals)

D. ENERGY CONSERVATION

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. evaluate initiatives and technological innovations related to energy consumption and conservation, and assess their impact on personal lifestyles, social attitudes, and the environment;

D2. investigate various methods of conserving energy and improving energy efficiency;

D3. demonstrate an understanding of the basic principles of energy production, with reference to both renewable and non-renewable sources, and of various methods of energy conservation.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 assess, on the basis of research, the impact that initiatives for reducing energy consumption and waste have on personal lifestyles, societal attitudes, and the environment (e.g., local, provincial, or national initiatives by government, business, or non-governmental organizations) [IP, PR, AI, C]

Sample issue: Home energy audit and retrofit rebate programs have been established by many provincial governments to help homeowners reduce their energy bills. Although these programs raise awareness of the environmental impact of wasting energy and provide practical ways of reducing waste, not all homeowners take advantage of them.

Sample questions: What types of incentives exist to encourage consumers to purchase energy-efficient products and services? How effective are such incentives? What methods do energy companies use to encourage consumers to conserve energy? What are some of the non-governmental organizations in Canada that raise awareness of the environmental costs of energy consumption? Are there any groups in your local community that focus on energy conservation? How effective are they?

D1.2 evaluate, on the basis of research, some of the advantages or disadvantages of technological innovations that contribute to the production of renewable energy and/or aid in conservation (e.g., bio-oil, biodiesel, wind turbines, improved insulation, programmable thermostats) [IP, PR, AI, C]

Sample issue: Tankless water heaters heat water only when it is needed. They save energy over traditional water heaters, which keep a large tank of water hot at all times. However, tankless water heaters may not be able to supply enough hot water for multiple uses.

Sample questions: What technologies are used to produce biofuels? How do these fuels help to reduce use of non-renewable energy? What problems might be associated with the use of agricultural crops for fuel rather than food? In what ways has the design of wind farm technology improved over the years? What are the advantages and disadvantages of replacing old appliances with more energy-efficient ones?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to energy conservation and consumption, including, but not limited to: *conventional source*, *alternative source*, *efficiency*, *watt*, *kilowatt-hour [kWh]*, *joule*, *BTU*, *gas meter*, *electric meter*, *thermostat*, and *EnerGuide* [C]

D2.2 determine the energy consumption of their household over a given time period by reading and interpreting gas and/or electric meters, calculate the cost of consumption (e.g., the number of kWh × cost per kWh, cubic metres of gas × cost per cubic metre), and suggest ways in which the household could conserve energy [PR, AI, C]

D2.3 use a research or inquiry process to compare the efficiency of different types or brands of a common household appliance (e.g., different brands of kettles, fans, or refrigerators; natural gas and electric water heaters) or of audio-visual equipment (e.g., different types of computer monitors), and report their findings [IP, PR, AI, C]

D2.4 conduct a risk-benefit analysis of different types of electricity generation (e.g., fossil fuel, hydro, nuclear, wind, and/or solar power) [PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the basic principles and characteristics of various types of power generation from non-renewable sources (e.g., coal, oil, natural gas, nuclear) and renewable sources (e.g., hydro-electric, tidal, geothermal, solar, wind, hydrogen fuel cells)

D3.2 compare and contrast renewable and non-renewable energy sources, using criteria such as availability, cost, and environmental impact (e.g., compare a fossil fuel and geothermal energy, using a graphic organizer)

D3.3 describe methods of energy conservation (e.g., the replacement of incandescent bulbs with compact fluorescent bulbs, the replacement of a manual thermostat with a programmable one, the installation of more energy-efficient windows) and some policies that are intended to manage energy demand in the home and the workplace (e.g., variable pricing, which increases the price of electricity during peak hours)

D3.4 describe several criteria used in the construction of energy-efficient buildings (e.g., "smart homes", in which the use of light, heat, and power for equipment can be programmed; R-2000 homes; straw-bale houses)

E. NATURAL RESOURCE SCIENCE AND MANAGEMENT

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. assess the environmental impact of the harvesting and/or extraction of resources, including ways of reducing this impact, and analyse threats to the sustainability of natural resources;

E2. investigate methods scientists use to classify and monitor natural resources, and conduct investigations using those methods;

E3. demonstrate an understanding of the sustainable use of resources and its relationship to the biodiversity and sustainability of ecosystems.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 assess the environmental impact of industrial practices related to the extracting or harvesting of natural resources, and describe ways in which that impact can be monitored and minimized [AI, C]

Sample issue: As a result of overfishing, several marine species are endangered. Bottom-trawling drag nets drown sea life, including mammals and turtles, who become entangled in them, and destroy seafloor habitat. In an effort to allow endangered species to recover, governments monitor populations, sometimes limiting catches or declaring moratoriums, and some countries have banned bottom trawling.

Sample questions: What impact can mine tailings have on local water? What practices can be used to reduce this impact? What impact does clear-cutting have on local ecosystems? What impact does large-scale deforestation have on the environment? What harvesting practices can the forestry industry use to minimize the effects of clear-cutting and deforestation?

E1.2 analyse, on the basis of research, the impact that an environmental contaminant, parasite, or bacteria has on the sustainability of a natural resource in Canada (e.g., the effects of PCBs on Arctic sea mammals, of sea lice on farmed and wild salmon, of E. coli on water resources) [IP, PR, AI, C]

Sample issue: As a result of warmer winters and a policy of fire suppression, the mountain pine beetle has decimated coniferous forests in British Columbia, killing millions of lodgepole pines, the most widely harvested tree in the province. There are fears that the beetle will expand into Alberta and could eventually harm pine forests across the country.

Sample questions: How have mercury levels in fish affected the local fishing industry in Northern Ontario? How has mange affected the fox population and people who depend on trapping? What impact has increased bacteria levels in inland waterways had on duck populations?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to natural resources and resource management, including, but not limited to: *population, bioamplification, sampling size, sustainability, ore, mineral, tailings,* and *succession* [C]

E2.2 identify and classify a variety of natural resources found in Canada, using appropriate classification systems (e.g., dichotomous keys, botanical keys, tree identification guides, wildlife guides, mineral tests) [PR, AI]

E2.3 investigate, through laboratory inquiry, field study, or simulations, some of the methods and procedures used by scientists to monitor biodiversity in different environments (e.g., making plant tallies in forests; tagging or marking ground vegetation species in fields; tagging and tracking wildlife with the global positioning system in remote areas; using aquatic dip nets for sampling organisms in shallow ponds or streams) [PR]

E2.4 conduct an inventory of a local environment (e.g., a field, a pond), using appropriate techniques and methods (e.g., plant tallies, tags, keys), and display the results graphically [PR, C]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe the main types of natural resources found in Canada (e.g., forests, minerals, fisheries, wildlife, water, fossil fuels)

E3.2 describe the characteristics and properties that make a natural resource viable for use (e.g., the size, type, and location of trees; the value, location, and extraction and processing costs of minerals), and explain the importance of managing natural resources to ensure sustainability and biodiversity

E3.3 describe a variety of methods used to extract or harvest natural resources (e.g., drag nets, strip mining, selective cutting of forests)

E3.4 explain how a variety of sampling techniques (e.g., quadrant sampling, catch-and-release, core sampling to measure tree rings, counting annuli in scales to measure the age of fish) are used to gather information about natural resources

E3.5 explain the importance of biodiversity to the sustainability of life within an ecosystem (e.g., variability among biotic and abiotic factors within an ecosystem decreases the chance that any organism within that ecosystem will become extinct)

E3.6 describe some methods that scientists use to monitor biodiversity in aquatic and terrestrial environments (e.g., field data collection, aerial and satellite imagery)

F. THE SAFE AND ENVIRONMENTALLY RESPONSIBLE WORKPLACE*

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. assess workplace situations with respect to safety and environmental issues, and propose a course of action to address unsafe working conditions;

F2. investigate a variety of safe and environmentally responsible workplace practices;

F3. demonstrate an understanding of general workplace safety procedures and environmentally responsible practices.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 analyse unsafe working conditions that can affect young workers in various workplace situations (e.g., using information from the Live Safe! Work Smart! website; using information obtained during a co-op placement or through experiential learning), and propose a course of action that would help to improve one such situation [AI, C]

Sample issue: A young worker is asked by her employer to place boxes on the top shelf of an eight-foot storage unit. However, no one is available to help her, and the only ladder in the workplace is unstable. She is unsure what action she should take.

Sample questions: What are the most frequent injuries among young workers? What types of jobs result in the most frequent and/or most serious injuries among young workers? How can the risks associated with these injuries be reduced? How should a young worker address a safety concern? How can companies be encouraged to create safe work environments?

F1.2 analyse, on the basis of research, and report on the environmental impact of unsafe handling, storage, and disposal of hazardous and non-hazardous workplace materials associated with a particular job [IP, PR, AI, C]

Sample issue: Home construction workers use a range of materials that can harm the environment. Spills of stains and solvents, improper disposal of paint and other chemical substances, the particulate matter created when wall board is cut or insulation is blown, and improper storage of combustible or corrosive materials can contaminate the air, water, and soil.

Sample questions: What impact does the improper storage and disposal of cooking oils in fast-food restaurants have on the environment? In what ways can improper handling or disposal of medical materials (e.g., pharmaceuticals, medical isotopes, disinfectants) in a hospital affect the environment? What is the environmental impact if fast-food restaurants do not separate their waste into compostable, recyclable, and non-recyclable materials?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to safety and environmental responsibility in the workplace, including, but not limited to: *Möbius loop*, *Material Safety Data Sheet (MSDS)*, *Hazardous Household Product Symbols (HHPS)*, *hazardous material*, and *personal protective equipment (PPE)* [C]

* Activities related to the achievement of expectations that refer to “the workplace” and/or that involve hazardous materials may be simulated in the classroom. It is the teacher’s responsibility to ensure students’ safety.

F2.2 demonstrate proper use of a variety of safety techniques and procedures after completing a recognized safety training program (e.g., a "virtual WHMIS" program such as Passport to Safety) [PR]

F2.3 conduct an inventory of hazardous products, safety equipment, and personal protective equipment found in a workplace, using an accepted tool (e.g., a FireSmart Assessment test from the Ministry of Natural Resources), and communicate the results using a table or checklist [PR, C]

F2.4 use appropriate techniques for handling, storing, and disposing of teacher-selected materials, drawing on Material Safety Data Sheets and Canadian Environmental Protection Act regulations (e.g., use appropriate personal protective equipment), and outline proper procedures for handling those materials in the workplace [PR, C]

F2.5 design and report on a plan for reusing, recycling, reducing the volume of, or disposing of a hazardous material found in the workplace (e.g., disposing of batteries, reusing motor or cooking oils for a different purpose) [IP, C]

F2.6 investigate the effectiveness of a personal protective device or environmental protection device for use in the workplace (e.g., compare two different spill kits for absorbing spills; test the key features of a mask for protection from airborne particulate matter; identify the appropriate types of eye protection for different situations) [PR, AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 describe some of the ways in which implementation of the 4Rs (reduce, reuse, recycle, and recover) in the workplace protects the environment (e.g., by reducing the production of garbage and recycling materials for daily use), and explain the meaning of different symbols used to promote these strategies (e.g., different representations of the Möbius loop [the international recycling symbol])

F3.2 compare some of the features, uses, and environmental implications of Hazardous Household Product Symbols and WHMIS hazard symbols

F3.3 identify and describe common types of biological, physical, and chemical hazards in the workplace (e.g., hazards posed by bacteria, noise, work at dangerous heights, use of chemicals and other hazardous materials) and associated accident-prevention methods (e.g., sterilization, soundproofing, use of five-point safety harnesses, use of safe storage cabinets, safe disposal of chemicals)

F3.4 explain how the use of personal protective equipment (e.g., aluminized gloves, a welding shield, ear plugs, a self-contained breathing apparatus, an air-purifying mask) minimizes exposure to hazardous materials that can enter the body through ingestion, inhalation, absorption, and injection

F3.5 identify some current workplace procedures, practices, and protocols that help to protect the environment (e.g., garbage separation, paper recycling, use of recycled products, "telecommuting" to workplaces, practices that conserve water and energy)

PHYSICS

Physics, Grade 11

University Preparation **SPH3U**

This course develops students' understanding of the basic concepts of physics. Students will explore kinematics, with an emphasis on linear motion; different kinds of forces; energy transformations; the properties of mechanical waves and sound; and electricity and magnetism. They will enhance their scientific investigation skills as they test laws of physics. In addition, they will 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

Big Ideas

Kinematics

- Motion involves a change in the position of an object over time.
- Motion can be described using mathematical relationships.
- Many technologies that apply concepts related to kinematics have societal and environmental implications.

Forces

- Forces can change the motion of an object.
- Applications of Newton's laws of motion have led to technological developments that affect society and the environment.

Energy and Society

- Energy can be transformed from one type to another.
- Energy transformation systems often involve thermal energy losses and are never 100% efficient.
- Although technological applications that involve energy transformations can affect society and the environment in positive ways, they can also have negative effects, and therefore must be used responsibly.

Waves and Sound

- Mechanical waves have specific characteristics and predictable properties.
- Sound is a mechanical wave.
- Mechanical waves can affect structures, society, and the environment in positive and negative ways.

Electricity and Magnetism

- Relationships between electricity and magnetism are predictable.
- Electricity and magnetism have many technological applications.
- Technological applications that involve electromagnetism and energy transformations can affect society and the environment in positive and negative ways.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Kinematics	Forces	Energy and Society	Waves and Sound	Electricity and Magnetism
Matter		✓	✓	✓	✓
Energy	✓	✓	✓	✓	✓
Systems and Interactions	✓	✓	✓	✓	✓
Structure and Function	✓	✓		✓	✓
Sustainability and Stewardship			✓	✓	✓
Change and Continuity			✓		

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., probeware, calorimeters, pendulums, solenoids) and materials (e.g., drag sleds, electric bells, balls, ramps), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation for qualitative and quantitative data (e.g., vector diagrams, free-body diagrams, algebraic equations)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., theoretical physicist; communications, networks, and control systems professional; engineer; metallurgist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Richard E. Taylor, Leonard T. Bruton, Willard S. Boyle, Martha Salcudean, Harriet Brooks, Louis Slotin), to the fields under study

B. KINEMATICS

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse technologies that apply concepts related to kinematics, and assess the technologies' social and environmental impact;

B2. investigate, in qualitative and quantitative terms, uniform and non-uniform linear motion, and solve related problems;

B3. demonstrate an understanding of uniform and non-uniform linear motion, in one and two dimensions.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse, on the basis of research, a technology that applies concepts related to kinematics (e.g., devices used to measure speed in sports; rocket accelerators; motion-detecting sensors for security systems; speedometers in automobiles) [IP, PR, AI, C]

Sample questions: How does a speed gun measure the motion of a ball thrown by a baseball pitcher? How are accelerometers used to study the motion of animals in wilderness settings? How are accelerometers used in video game consoles? What type of device is used to monitor false starts in a sprint? How does it work?

B1.2 assess the impact on society and the environment of a technology that applies concepts related to kinematics (e.g., photo radar helps prevent vehicular accidents and reduces fuel consumption associated with excessive speeding) [AI, C]

Sample issue: The use of the global positioning system (GPS) increases accuracy in mapping, surveying, navigation, monitoring earthquakes, and tracking the movement of oil spills and forest fires, among other benefits. However, its extensive use raises concerns about privacy and human rights.

Sample questions: How are satellites used to track animal species in remote areas? How can scientists and environmentalists use this information to help protect vulnerable species? What is the impact of the use of speed limiters and tracking devices in the trucking industry? What effect do lower truck speeds have on highway safety and vehicle emissions?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to kinematics, including, but not limited to: *time, distance, position, displacement, speed, velocity,* and *acceleration* [C]

B2.2 analyse and interpret position–time, velocity–time, and acceleration–time graphs of motion in one dimension (e.g., use tangent slopes to create velocity–time graphs from position–time graphs and acceleration–time graphs from velocity–time graphs; use the area under the curve to create position–time graphs from velocity–time graphs and velocity–time graphs from acceleration–time graphs) [AI, C]

B2.3 use a velocity–time graph for constant acceleration to derive the equation for average velocity [e.g., $v_{av} = (v_1 + v_2)/2$] and the equations for displacement [e.g., $\Delta d = ((v_1 + v_2)/2)\,\Delta t$, $\Delta d = v_1\Delta t + ½\, a\,(\Delta t^2)$], and solve simple problems in one dimension using these equations [AI]

B2.4 conduct an inquiry into the uniform and non-uniform linear motion of an object (e.g., use probeware to record the motion of a cart moving at a constant velocity or a constant acceleration; view a computer simulation of an object attaining terminal velocity; observe a video of a bouncing ball or a skydiver; observe the motion of a balloon with a small mass suspended from it) [PR]

B2.5 solve problems involving distance, position, and displacement (e.g., find total displacement using a scale vector diagram and vector components, and compare it to total distance travelled) [AI, C]

B2.6 plan and conduct an inquiry into the motion of objects in one dimension, using vector diagrams and uniform acceleration equations [IP, PR, C]

B2.7 solve problems involving uniform and non-uniform linear motion in one and two dimensions, using graphical analysis and algebraic equations [AI, C]

B2.8 use kinematic equations to solve problems related to the horizontal and vertical components of the motion of a projectile (e.g., a cannon ball shot horizontally off a cliff, a ball rolling off a table, a golf ball launched at a 45º angle to the horizontal) [AI, C]

B2.9 conduct an inquiry into the projectile motion of an object, and analyse, in qualitative and quantitative terms, the relationship between the horizontal and vertical components (e.g., airborne time, range, maximum height, horizontal velocity, vertical velocity) [PR, AI]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 distinguish between the terms *constant*, *instantaneous*, and *average* with reference to speed, velocity, and acceleration, and provide examples to illustrate each term

B3.2 distinguish between, and provide examples of, scalar and vector quantities as they relate to the description of uniform and non-uniform linear motion (e.g., time, distance, position, velocity, acceleration)

B3.3 describe the characteristics and give examples of a projectile's motion in vertical and horizontal planes

C. FORCES

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse and propose improvements to technologies that apply concepts related to dynamics and Newton's laws, and assess the technologies' social and environmental impact;

C2. investigate, in qualitative and quantitative terms, net force, acceleration, and mass, and solve related problems;

C3. demonstrate an understanding of the relationship between changes in velocity and unbalanced forces in one dimension.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse, with reference to Newton's laws, a technology that applies these laws (e.g., extremely low friction bearings, near frictionless carbon, different types of athletic shoes, roller coasters), and propose ways to improve its performance [AI, C]

Sample questions: What factors are taken into consideration in the design of golf clubs? What element(s) could be changed to improve a club's performance? How do anti-lock brakes work, and what limitations do they have? What impact does the condition of the road (wet, dry, smooth, grooved) have on the forces acting on the braking of a skidding car? What are the benefits and limitations of electronic stability controls (ESC) on automobiles?

C1.2 evaluate the impact on society and the environment of technologies that use the principles of force (e.g., prosthetics, plastic car bodies) [AI, C]

Sample issue: Before the 1960s, when car bodies were strong and rigid, passengers tended to be severely injured during collisions. The introduction of technologies that absorb or dissipate force, such as crumple zones, seat belts, and air bags, has reduced serious automobile injuries and the social costs associated with them.

Sample questions: How do snow tires reduce the risk of traffic accidents in the winter? How does society benefit from this risk reduction? What are the advantages and disadvantages for the environment of various methods of using the natural forces from tidal currents to generate energy?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to forces, including, but not limited to: *mass*, *time*, *speed*, *velocity*, *acceleration*, *friction*, *gravity*, *normal force*, and *free-body diagrams* [C]

C2.2 conduct an inquiry that applies Newton's laws to analyse, in qualitative and quantitative terms, the forces acting on an object, and use free-body diagrams to determine the net force and the acceleration of the object [PR, AI, C]

C2.3 conduct an inquiry into the relationship between the acceleration of an object and its net force and mass (e.g., view a computer simulation of an object attaining terminal velocity; observe the motion of an object subject to friction; use electronic probes to observe the motion of an object being pulled across the floor), and analyse the resulting data [PR, AI]

C2.4 analyse the relationships between acceleration and applied forces such as the force of gravity, normal force, force of friction, coefficient of static friction, and coefficient of kinetic friction, and solve related problems involving forces in one dimension, using free-body diagrams and algebraic equations (e.g., use a drag sled to find the coefficient of friction between two surfaces) [AI, C]

C2.5 plan and conduct an inquiry to analyse the effect of forces acting on objects in one dimension, using vector diagrams, free-body diagrams, and Newton's laws [IP, PR, AI, C]

C2.6 analyse and solve problems involving the relationship between the force of gravity and acceleration for objects in free fall [AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 distinguish between, and provide examples of, different forces (e.g., friction, gravity, normal force), and describe the effect of each type of force on the velocity of an object

C3.2 explain how the theories and discoveries of Galileo and Newton advanced knowledge of the effects of forces on the motion of objects

C3.3 state Newton's laws, and apply them, in qualitative terms, to explain the effect of forces acting on objects

C3.4 describe, in qualitative and quantitative terms, the relationships between mass, gravitational field strength, and force of gravity

D. ENERGY AND SOCIETY

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse technologies that apply principles of and concepts related to energy transformations, and assess the technologies' social and environmental impact;

D2. investigate energy transformations and the law of conservation of energy, and solve related problems;

D3. demonstrate an understanding of work, efficiency, power, gravitational potential energy, kinetic energy, nuclear energy, and thermal energy and its transfer (heat).

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse, using the principles of energy transformations, a technology that involves the transfer and transformation of thermal energy (e.g., a power station, an air conditioner, a fuel cell, a laser printer) [AI, C]

Sample questions: How do vertical or rooftop gardens help insulate structures? In what ways have refrigeration technologies changed since their initial development? When they are designed efficiently, how do homes with solar-powered cells use the energy from the sun? How do ground-source heat pumps reduce the need for traditional heating and cooling systems?

D1.2 assess, on the basis of research, how technologies related to nuclear, thermal, or geothermal energy affect society and the environment (e.g., thermal regulating units, radiopharmaceuticals, dry-steam power plants, ground-source heat pumps) [IP, PR, AI, C]

Sample issue: With the rising economic and environmental costs of heating homes using conventional methods, geothermal technologies are an increasingly popular alternative. However, tapping geothermal heat sources involves placing kilometres of tubing containing antifreeze in the ground, which constitutes a potential environmental hazard.

Sample questions: How is the nuclear technology known as receptor binding assay used to monitor the toxicity of shellfish? How does this technology benefit consumers? How can nuclear technology be used to sterilize insects? If used widely, what impact would such a pest-control technique have on society and the environment? What is the benefit of using fast-freeze technologies in cold chain shipping for highly perishable goods?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to energy transformations, including, but not limited to: *mechanical energy, gravitational potential energy, kinetic energy, work, power, fission, fusion, heat, heat capacity, temperature,* and *latent heat* [C]

D2.2 solve problems relating to work, force, and displacement along the line of force [AI]

D2.3 use the law of conservation of energy to solve problems in simple situations involving work, gravitational potential energy, kinetic energy, and thermal energy and its transfer (heat) [AI]

D2.4 plan and conduct inquiries involving transformations between gravitational potential energy and kinetic energy (e.g., using a pendulum, a falling ball, an object rolling down a ramp) to test the law of conservation of energy [IP, PR]

D2.5 solve problems involving the relationship between power, energy, and time [AI]

D2.6 conduct inquiries and solve problems involving the relationship between power and work (e.g., the power of a student using different types of fitness equipment) [PR, AI]

D2.7 compare and contrast the input energy, useful output energy, and per cent efficiency of selected energy generation methods (e.g., hydroelectric, thermal, geothermal, nuclear fission, nuclear fusion, wind, solar) [AI, C]

D2.8 investigate the relationship between the concepts of conservation of mass and conservation of energy, and solve problems using the mass–energy equivalence [PR, AI]

D2.9 conduct an inquiry to determine the specific heat capacity of a single substance (e.g., aluminum, iron, brass) and of two substances when they are mixed together (e.g., the heat lost by a sample of hot water and the heat gained by a sample of cold water when the two samples are mixed together) [PR]

D2.10 solve problems involving changes in temperature and changes of state, using algebraic equations (e.g., $Q = mc\Delta T$, $Q = mL_f$, $Q = mL_v$) [AI, C]

D2.11 draw and analyse heating and cooling curves that show temperature changes and changes of state for various substances [AI, C]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 describe a variety of energy transfers and transformations, and explain them using the law of conservation of energy

D3.2 explain the concepts of and interrelationships between energy, work, and power, and identify and describe their related units

D3.3 explain the following concepts, giving examples of each, and identify their related units: *thermal energy, kinetic energy, gravitational potential energy, heat, specific heat capacity, specific latent heat, power,* and *efficiency*

D3.4 identify, qualitatively, the relationship between efficiency and thermal energy transfer

D3.5 describe, with reference to force and displacement along the line of force, the conditions that are required for work to be done

D3.6 describe and compare nuclear fission and nuclear fusion

D3.7 explain, using the kinetic molecular theory, the energy transfer that occurs during changes of state

D3.8 distinguish between and provide examples of conduction, convection, and radiation

D3.9 identify and describe the structure of common nuclear isotopes (e.g., hydrogen, deuterium, tritium)

D3.10 compare the characteristics of (e.g., mass, charge, speed, penetrating power, ionizing ability) and safety precautions related to alpha particles, beta particles, and gamma rays

D3.11 explain radioactive half-life for a given radioisotope, and describe its applications and their consequences

D3.12 explain the energy transformations that occur within a nuclear power plant, with reference to the laws of thermodynamics (e.g., nuclear fission results in the liberation of energy, which is converted into thermal energy; the thermal energy is converted into electrical energy and waste heat, using a steam turbine)

E. WAVES AND SOUND

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse how mechanical waves and sound affect technology, structures, society, and the environment, and assess ways of reducing their negative effects;

E2. investigate, in qualitative and quantitative terms, the properties of mechanical waves and sound, and solve related problems;

E3. demonstrate an understanding of the properties of mechanical waves and sound and of the principles underlying their production, transmission, interaction, and reception.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse how properties of mechanical waves and sound influence the design of structures and technological devices (e.g., the acoustical design of a concert hall; the design of headphones, hearing aids, musical instruments, wave pools) [AI, C]

Sample issue: Waves cause vibrations when they oscillate at different frequencies. Oscillating waves caused by wind or earthquakes can threaten the structure of bridges if they are not properly designed. Engineers have developed different designs of bridges, depending on local conditions, but no single design can take all possible wave frequencies into account.

Sample questions: How do energy-conversion buoys use the properties of waves to generate electricity? Why do different musical instruments produce different sounds? What features need to be incorporated into the acoustic design of an outdoor concert venue in order for it to provide optimal sound quality for the audience but limited noise in the surrounding area?

E1.2 analyse the negative impact that mechanical waves and/or sound can have on society and the environment, and assess the effectiveness of a technology intended to reduce this impact [AI, C]

Sample issue: Noise pollution from industrial, transportation, entertainment, and other sources can increase stress, lead to hearing loss, disrupt ecosystems, and alter animal behaviour. Noise pollution can be reduced by using mufflers, sound barriers, baffles, and earplugs, and by turning down the volume on devices such as cellphones and headsets.

Sample questions: What impact can tsunamis have on coastal regions? How effective is tsunami-monitoring equipment in reducing death tolls and property destruction? How do the noise levels produced by different types of jet engines compare with each other? How effective are the sound baffles erected on the sides of highways that run through residential areas?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to mechanical waves and sound, including, but not limited to: *longitudinal wave*, *transverse wave*, *frequency*, *period*, *cycle*, *amplitude*, *phase*, *wavelength*, *velocity*, *superposition*, *constructive interference*, *destructive interference*, *standing waves*, and *resonance* [C]

E2.2 conduct laboratory inquiries or computer simulations involving mechanical waves and their interference (e.g., using a mass oscillating on a spring, a mass oscillating on a pendulum, the oscillation in a string instrument) [PR]

E2.3 plan and conduct inquiries to determine the speed of waves in a medium (e.g., a vibrating air column, an oscillating string of a musical instrument), compare theoretical and empirical values, and account for discrepancies [IP, PR, AI, C]

E2.4 investigate the relationship between the wavelength, frequency, and speed of a wave, and solve related problems [PR, AI]

E2.5 analyse the relationship between a moving source of sound and the change in frequency perceived by a stationary observer (i.e., the Doppler effect) [AI]

E2.6 predict the conditions needed to produce resonance in vibrating objects or air columns (e.g., in a wind instrument, a string instrument, a tuning fork), and test their predictions through inquiry [IP, PR, AI]

E2.7 analyse the conditions required to produce resonance in vibrating objects and/or in air columns (e.g., in a string instrument, a tuning fork, a wind instrument), and explain how resonance is used in a variety of situations (e.g., to produce different notes in musical instruments; to limit undesirable vibrations in suspension bridges; to design buildings so that they do not resonate at the frequencies produced by earthquakes) [AI, C]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 distinguish between longitudinal and transverse waves in different media, and provide examples of both types of waves

E3.2 explain the components of resonance, and identify the conditions required for resonance to occur in vibrating objects and in various media (e.g., with reference to a musical instrument, a child on a swing, the Tacoma Narrows Bridge)

E3.3 explain and graphically illustrate the principle of superposition with respect to standing waves and beat frequencies

E3.4 identify the properties of standing waves, and, for both mechanical and sound waves, explain the conditions required for standing waves to occur

E3.5 explain the relationship between the speed of sound in various media and the particle nature of the media (e.g., the speed of sound in solids, liquids, and gases; the speed of sound in warm and cold air)

E3.6 explain selected natural phenomena (e.g., echo location, or organisms that produce or receive infrasonic, audible, or ultrasonic sound) with reference to the characteristics and properties of waves

F. ELECTRICITY AND MAGNETISM

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse the social, economic, and environmental impact of electrical energy production and technologies related to electromagnetism, and propose ways to improve the sustainability of electrical energy production;

F2. investigate, in qualitative and quantitative terms, magnetic fields and electric circuits, and solve related problems;

F3. demonstrate an understanding of the properties of magnetic fields, the principles of current and electron flow, and the operation of selected technologies that use these properties and principles to produce and transmit electrical energy.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 analyse the social and economic impact of technologies related to electromagnetism (e.g., particle accelerators, mass spectrometers, magnetic levitation [maglev] trains, magnetic resonance imaging [MRI], electromagnetic pulses after nuclear explosions) [AI, C]

Sample issue: The use of red-light camera technology at busy intersections has decreased the number of accidents and pedestrian fatalities. However, some people view the use of this technology as an unnecessary intrusion by "Big Brother".

Sample questions: What are the benefits of electromagnetic medical technologies? What impact does the cost of acquiring these technologies, and the need for specialized technicians to operate them, have on equitable access to health care in all regions of Canada? What harmful effects do solar flares have on our atmosphere, satellites orbiting the earth, and electrical systems?

F1.2 analyse the efficiency and the environmental impact of one type of electrical energy production (e.g., from hydroelectric, fossil fuel–burning, wind, solar, geothermal, or nuclear sources), and propose ways to improve the sustainability of electrical energy production [AI, C]

Sample issue: Compared to oil, coal is relatively inexpensive and plentiful, and, globally, the number of coal-burning electrical plants is expanding. Yet, coal power is inefficient, and the mining and burning of coal produce a great deal of pollution. Although technology is available to make coal cleaner, it is costly and has been implemented to only a limited extent.

Sample questions: How efficient are the small- and large-scale solar-power systems used in individual homes and industrial settings? What is the environmental impact of the generation of solar power? What technologies are being used to improve the efficiency of energy sources such as coal and biofuel? What impact does the increasing use of biofuels have on air quality, land use, and agricultural practices?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to electricity and magnetism, including, but not limited to: *direct current*, *alternating current*, *conventional current*, *electron flow*, *electrical potential difference*, *electrical resistance*, *power*, *energy*, *step-up transformer*, and *step-down transformer* [C]

F2.2 analyse diagrams of series, parallel, and mixed circuits with reference to Ohm's law ($V = IR$) and Kirchhoff's laws [AI]

F2.3 design and build real or computer-simulated mixed direct current (DC) circuits, and explain the circuits with reference to direct current, potential difference, and resistance [PR, C]

F2.4 conduct an inquiry to identify the characteristics and properties of magnetic fields (e.g., using magnetic compasses, iron filings, and electric and magnetic field sensors) [PR]

F2.5 investigate, through laboratory inquiry or computer simulation, the magnetic fields produced by an electric current flowing through a long straight conductor and a solenoid (e.g., use sensors to map the magnetic field around a solenoid) [PR]

F2.6 solve problems involving energy, power, potential difference, current, and the number of turns in the primary and secondary coils of a transformer [AI]

F2.7 investigate electromagnetic induction, and, using Lenz's law, the law of conservation of energy, and the right-hand rule, explain and illustrate the direction of the electric current induced by a changing magnetic field [PR, AI, C]

F2.8 construct a prototype of a device that uses the principles of electromagnetism (e.g., an electric bell, loudspeaker, ammeter, electric motor, electric generator), and test and refine their device [PR, AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 describe the properties of magnetic fields in permanent magnets and electromagnets (e.g., the three-dimensional nature of fields, continuous field lines, fields around current-carrying conductors and coils)

F3.2 explain, 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

F3.3 distinguish between conventional current and electron flow in relation to the left- and right-hand rules

F3.4 explain Ohm's law, Kirchhoff's laws, Oersted's principle, the motor principle, Faraday's law, and Lenz's law in relation to electricity and magnetism

F3.5 describe the production and interaction of magnetic fields, using diagrams and the principles of electromagnetism (e.g., Oersted's principle, the motor principle, Faraday's law, Lenz's law)

F3.6 explain the operation of an electric motor and a generator, including the roles of their respective components

F3.7 distinguish between alternating current (AC) and direct current, and explain why alternating current is presently used in the transmission of electrical energy

F3.8 describe the components of step-up and step-down transformers, and, using concepts and principles related to electric current and magnetic fields, explain the operation of these transformers

F3.9 describe and explain safety precautions (e.g., "call before you dig", current-limiting outlets in bathrooms) related to electrical circuits and higher transmission voltages (e.g., with reference to transformer substations, buried cables, overhead power lines)

Physics, Grade 12

University Preparation SPH4U

This course enables students to deepen their understanding of physics concepts and theories. Students will continue their exploration of energy transformations and the forces that affect motion, and will investigate electrical, gravitational, and magnetic fields and electromagnetic radiation. Students will also explore the wave nature of light, quantum mechanics, and special relativity. They will further develop their scientific investigation skills, learning, for example, how to analyse, qualitatively and quantitatively, data related to a variety of physics concepts and principles. Students will also consider the impact of technological applications of physics on society and the environment.

Prerequisite: Physics, Grade 11, University Preparation

Big Ideas

Dynamics

- Forces affect motion in predictable and quantifiable ways.
- Forces acting on an object will determine the motion of that object.
- Many technologies that utilize the principles of dynamics have societal and environmental implications.

Energy and Momentum

- Energy and momentum are conserved in all interactions.
- Interactions involving the laws of conservation of energy and conservation of momentum can be analysed mathematically.
- Technological applications that involve energy and momentum can affect society and the environment in positive and negative ways.

Gravitational, Electric, and Magnetic Fields

- Gravitational, electric, and magnetic forces act on matter from a distance.
- Gravitational, electric, and magnetic fields share many similar properties.
- The behaviour of matter in gravitational, electric, and magnetic fields can be described mathematically.
- Technological systems that involve gravitational, electric, and magnetic fields can have an effect on society and the environment.

The Wave Nature of Light

- Light has properties that are similar to the properties of mechanical waves.
- The behaviour of light as a wave can be described mathematically.
- Technologies that use the principles of the wave nature of light can have societal and environmental implications.

Revolutions in Modern Physics: Quantum Mechanics and Special Relativity

- Light can show particle-like and wave-like behaviour, and particles can show wave-like behaviour.
- The behaviour of light as a particle and the behaviour of particles as waves can be described mathematically.

- Time is relative to a person's frame of reference.
- The effects of relativistic motion can be described mathematically.
- New theories can change scientific thought and lead to the development of new technologies.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Dynamics	Energy and Momentum	Gravitational, Electric, and Magnetic Fields	The Wave Nature of Light	Revolutions in Modern Physics: Quantum Mechanics and Special Relativity
Matter	✓	✓	✓	✓	✓
Energy	✓	✓	✓	✓	✓
Systems and Interactions	✓	✓	✓		
Structure and Function	✓	✓	✓	✓	
Sustainability and Stewardship		✓		✓	
Change and Continuity		✓			✓

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., pendulums, springs, ripple tanks, lasers) and materials (e.g., sliding blocks, inclined planes), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., vector diagrams, free-body diagrams, vector components, and algebraic equations)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., laser optics researcher, geoscientist, photonics researcher, aerospace engineer) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Elizabeth MacGill, Pierre Coulombe, Allan Carswell, Gerhard Herzberg), to the fields under study

B. DYNAMICS

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse technological devices that apply the principles of the dynamics of motion, and assess the technologies' social and environmental impact;

B2. investigate, in qualitative and quantitative terms, forces involved in uniform circular motion and motion in a plane, and solve related problems;

B3. demonstrate an understanding of the forces involved in uniform circular motion and motion in a plane.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse a technological device that applies the principles of linear or circular motion (e.g., a slingshot, a rocket launcher, a race car, a trebuchet) [AI, C]

Sample questions: What aspects of the principles of motion are applied in archery? How does the equipment used by competitive skiers reduce friction and resistance? How does a "pop bottle" rocket use the principles of motion? How does the spin cycle of a washing machine use circular motion to remove water from clothes?

B1.2 assess the impact on society and the environment of technological devices that use linear or circular motion (e.g., projectile weapons, centrifuges, elevators) [AI, C]

Sample issue: Satellites, which use principles of circular motion to revolve around Earth, support communications technologies and are used by governments to gather intelligence. They also provide information on the movement of animal populations and forest fires, and on changes in weather systems or the atmosphere. But satellites use huge amounts of fuel, and old satellites often become space junk.

Sample questions: How are large-scale centrifuges used in wastewater treatment? How do windmills use the principles of dynamics to generate power? What is the environmental impact of wind power and wind farms? How are linear actuators used to make the workplace more ergonomic, reducing work days lost to strain and injury?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to dynamics, including, but not limited to: *inertial and non-inertial frames of reference*, *components*, *centripetal*, *period*, *frequency*, *static friction*, and *kinetic friction* [C]

B2.2 solve problems related to motion, including projectile and relative motion, by adding and subtracting two-dimensional vector quantities, using vector diagrams, vector components, and algebraic methods [PR, AI, C]

B2.3 analyse, in qualitative and quantitative terms, the relationships between the force of gravity, normal force, applied force, force of friction, coefficient of static friction, and coefficient of kinetic friction, and solve related two-dimensional problems using free-body diagrams, vector components, and algebraic equations (e.g., calculate the acceleration of a block sliding along an inclined plane or the force acting on a vehicle navigating a curve) [AI, C]

B2.4 predict, in qualitative and quantitative terms, the forces acting on systems of objects (e.g., masses in a vertical pulley system [a "dumb waiter"], a block sliding off an accelerating vehicle, masses in an inclined-plane pulley system), and plan and conduct an inquiry to test their predictions [IP, PR, AI]

B2.5 analyse, in qualitative and quantitative terms, the relationships between the motion of a system and the forces involved (e.g., a block sliding on an inclined plane, acceleration of a pulley system), and use free-body diagrams and algebraic equations to solve related problems [AI, C]

B2.6 analyse, in qualitative and quantitative terms, the forces acting on and the acceleration experienced by an object in uniform circular motion in horizontal and vertical planes, and use free-body diagrams and algebraic equations to solve related problems [AI, C]

B2.7 conduct inquiries into the uniform circular motion of an object (e.g., using video analysis of an amusement park ride, measuring the forces and period of a tether ball), and analyse, in qualitative and quantitative terms, the relationships between centripetal acceleration, centripetal force, radius of orbit, period, frequency, mass, and speed [PR, AI]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 distinguish between reference systems (inertial and non-inertial) with respect to the real and apparent forces acting within such systems (e.g., apparent force in a rotating frame, apparent gravitational force in a vertically accelerating frame, real force pulling on the elastic of a ball-and-paddle toy)

B3.2 explain the advantages and disadvantages of static and kinetic friction in situations involving various planes (e.g., a horizontal plane, a variety of inclined planes)

B3.3 explain the derivation of equations for uniform circular motion that involve the variables frequency, period, radius speed, and mass

C. ENERGY AND MOMENTUM

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse, and propose ways to improve, technologies or procedures that apply principles related to energy and momentum, and assess the social and environmental impact of these technologies or procedures;

C2. investigate, in qualitative and quantitative terms, through laboratory inquiry or computer simulation, the relationship between the laws of conservation of energy and conservation of momentum, and solve related problems;

C3. demonstrate an understanding of work, energy, momentum, and the laws of conservation of energy and conservation of momentum, in one and two dimensions.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse, with reference to the principles of energy and momentum, and propose practical ways to improve, a technology or procedure that applies these principles (e.g., fireworks, rocket propulsion, protective equipment, forensic analysis of vehicle crashes, demolition of buildings) [AI, C]

Sample issue: Sports helmets are designed to absorb energy from falls and collisions, reducing the number and severity of head injuries. Helmets must be light enough not to hamper performance while providing optimal protection.

Sample questions: How are principles of energy and momentum used in the design of amusement park rides, such as roller coasters and swing rides? How could the rides be improved, either in terms of their function or their safety? How does a child car seat help protect children riding in motor vehicles? How might the design of or materials used in standard child car seats be improved?

C1.2 assess the impact on society and the environment of technologies or procedures that apply the principles of energy and momentum (e.g., crumple zones, safety restraints, strategic building implosion) [AI, C]

Sample issue: Hydroelectricity is produced by using the potential energy of dammed water to drive turbines and generators. Although hydroelectricity is renewable and generates no greenhouse gases, the damming of waterways can create massive flooding upstream and reduce flows downstream, affecting aquatic and terrestrial ecosystems and people living near the water source.

Sample questions: Why do researchers use crash test dummies in simulated motor vehicle accidents? What impact have innovations such as seat belts and airbags had on injuries resulting from traffic accidents and on the associated health care costs? What is the environmental impact of the chemicals whose combustion produces the effects in fireworks displays?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to energy and momentum, including, but not limited to: *work, work–energy theorem, kinetic energy, gravitational potential energy, elastic potential energy, thermal energy, impulse, change in momentum–impulse theorem, elastic collision,* and *inelastic collision* [C]

C2.2 analyse, in qualitative and quantitative terms, the relationship between work and energy, using the work–energy theorem and the law of conservation of energy, and solve related problems in one and two dimensions [PR, AI]

C2.3 use an inquiry process to analyse, in qualitative and quantitative terms, situations involving work, gravitational potential energy, kinetic energy, thermal energy, and elastic potential energy, in one and two dimensions (e.g., a block sliding along an inclined plane with friction; a cart rising and falling on a roller coaster track; an object, such as a mass attached to a spring pendulum, that undergoes simple harmonic motion), and use the law of conservation of energy to solve related problems [PR, AI]

C2.4 conduct a laboratory inquiry or computer simulation to test the law of conservation of energy during energy transformations that involve gravitational potential energy, kinetic energy, thermal energy, and elastic potential energy (e.g., using a bouncing ball, a simple pendulum, a computer simulation of a bungee jump) [PR, AI]

C2.5 analyse, in qualitative and quantitative terms, the relationships between mass, velocity, kinetic energy, momentum, and impulse for a system of objects moving in one and two dimensions (e.g., an off-centre collision of two masses on an air table, two carts recoiling from opposite ends of a released spring), and solve problems involving these concepts [PR, AI]

C2.6 analyse, in qualitative and quantitative terms, elastic and inelastic collisions in one and two dimensions, using the laws of conservation of momentum and conservation of energy, and solve related problems [PR, AI]

C2.7 conduct laboratory inquiries or computer simulations involving collisions and explosions in one and two dimensions (e.g., interactions between masses on an air track, the collision of two pucks on an air table, collisions between spheres of similar and different masses) to test the laws of conservation of momentum and conservation of energy [PR, AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 describe and explain Hooke's law, and explain the relationships between that law, work, and elastic potential energy in a system of objects

C3.2 describe and explain the simple harmonic motion (SHM) of an object, and explain the relationship between SHM, Hooke's law, and uniform circular motion

C3.3 distinguish between elastic and inelastic collisions

C3.4 explain the implications of the laws of conservation of energy and conservation of momentum with reference to mechanical systems (e.g., damped harmonic motion in shock absorbers, the impossibility of developing a perpetual motion machine)

C3.5 explain how the laws of conservation of energy and conservation of momentum were used to predict the existence and properties of the neutrino

D. GRAVITATIONAL, ELECTRIC, AND MAGNETIC FIELDS

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse the operation of technologies that use gravitational, electric, or magnetic fields, and assess the technologies' social and environmental impact;

D2. investigate, in qualitative and quantitative terms, gravitational, electric, and magnetic fields, and solve related problems;

D3. demonstrate an understanding of the concepts, properties, principles, and laws related to gravitational, electric, and magnetic fields and their interactions with matter.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse the operation of a technological system that uses gravitational, electric, or magnetic fields (e.g., a home entertainment system, a computer, magnetic strips on credit cards) [AI, C]

Sample questions: How are gravitational field maps used to correct errors in navigational systems used in unmanned underwater vehicles (UUVs)? How are magneto-rheological (MR) fluid dampers used in buildings to absorb the shocks from earthquakes? How can radio frequency identification (RFID) chips be used for inventory tracking in stores and warehouses?

D1.2 assess the impact on society and the environment of technologies that use gravitational, electric, or magnetic fields (e.g., satellites used in surveillance or storm tracking, particle accelerators that provide high-energy particles for medical imaging) [AI, C]

Sample issue: The radiation produced by the magnetic and electric fields of electron accelerators is used to treat tumours. In conjunction with other therapies, radiation increases the survival rate of cancer patients, but safeguards are needed to ensure that patients receive safe doses of radiation and that medical personnel and the immediate environment are not contaminated.

Sample questions: What are some of the uses of particle accelerators, and how have these benefited society? What is the effect on human health of long-term exposure to the electrical fields created by high-voltage lines? How could zero-gravity experiments on agricultural products benefit society and the environment? What are the environmental benefits of using technology involving gravitational fields to search for mineral deposits?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to fields, including, but not limited to: *forces*, *potential energies*, *potential*, and *exchange particles* [C]

D2.2 analyse, and solve problems relating to, Newton's law of universal gravitation and circular motion (e.g., with respect to satellite orbits, black holes, dark matter) [AI]

D2.3 analyse, and solve problems involving, electric force, field strength, potential energy, and potential as they apply to uniform and non-uniform electric fields (e.g., the fields produced by a parallel plate and by point charges) [AI]

D2.4 analyse, and solve problems involving, the force on charges moving in a uniform magnetic field (e.g., the force on a current-carrying conductor or a free electron) [AI]

D2.5 conduct a laboratory inquiry or computer simulation to examine the behaviour of a particle in a field (e.g., test Coulomb's law; replicate Millikan's experiment or Rutherford's scattering experiment; use a bubble or cloud chamber) [PR]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 identify, and compare the properties of, fundamental forces that are associated with different theories and models of physics (e.g., the theory of general relativity and the standard model of particle physics)

D3.2 compare and contrast the corresponding properties of gravitational, electric, and magnetic fields (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields)

D3.3 use field diagrams to explain differences in the sources and directions of fields, including, but not limited to, differences between near-Earth and distant fields, parallel plates and point charges, straight line conductors and solenoids

E. THE WAVE NATURE OF LIGHT

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse technologies that use the wave nature of light, and assess their impact on society and the environment;

E2. investigate, in qualitative and quantitative terms, the properties of waves and light, and solve related problems;

E3. demonstrate an understanding of the properties of waves and light in relation to diffraction, refraction, interference, and polarization.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse, with reference to the principles related to the wave nature of light, a technology that uses these principles (e.g., Xeon lights, spectroscopes, polarized sunglasses) [AI, C]

Sample questions: How do geologists use the wave nature of light to find mineral deposits? How do surface plasmon polaritons (SPPs) make use of the wave nature of light? What are some of the applications of SPPs? How does the global positioning system (GPS) use the wave nature of light? What are its applications? What are its shortcomings?

E1.2 assess the impact on society and the environment of technologies that use the wave nature of light (e.g., DVDs, polarized lenses, night vision goggles, wireless networks) [AI, C]

Sample issue: Fibre optical technology has revolutionized access to information. Some people argue that unrestricted access to information helps to open up societies and improve human rights and can be used as tools for pro-democracy groups. However, some totalitarian governments practise censorship by restricting citizens' access to Internet sites promoting human rights and democracy.

Sample questions: How has holographic technology made it more difficult to counterfeit Canadian currency? In what ways does the use of lasers in surgery improve surgical techniques and recovery time? In what ways can posting magazines or newsletters on the Internet, rather than printing and distributing them, benefit the environment?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to the wave nature of light, including, but not limited to: *diffraction*, *dispersion*, *wave interference*, *nodal line*, *phase*, *oscillate*, *polarization*, and *electromagnetic radiation* [C]

E2.2 conduct inquiries involving the diffraction and interference of waves, using ripple tanks or computer simulations [PR]

E2.3 conduct inquiries involving the diffraction, refraction, polarization, and interference of light waves (e.g., shine lasers through single, double, and multiple slits; observe a computer simulation of Young's double-slit experiment; measure the index of refraction of different materials; observe the effect of crossed polarizing filters on transmitted light) [PR]

E2.4 analyse diffraction and interference of water waves and light waves (e.g., with reference to two-point source interference in a ripple tank, thin-film interference, multiple-slit interference), and solve related problems [PR, AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe and explain the diffraction and interference of water waves in two dimensions

E3.2 describe and explain the diffraction, refraction, polarization, and interference of light waves (e.g., reduced resolution caused by diffraction, mirages caused by refraction, polarization caused by reflection and filters, thin-film interference in soap films and air wedges, interference of light on CDs)

E3.3 use the concepts of refraction, diffraction, polarization, and wave interference to explain the separation of light into colours in various situations (e.g., light travelling through a prism; light contacting thin film, soap film, stressed plastic between two polarizing filters)

E3.4 describe, in qualitative terms, the production of electromagnetic radiation by an oscillating electric dipole (e.g., a radio transmitter, a microwave emitter, an X-ray emitter, electron energy transitions in an atom)

F. REVOLUTIONS IN MODERN PHYSICS: QUANTUM MECHANICS AND SPECIAL RELATIVITY

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse, with reference to quantum mechanics and relativity, how the introduction of new conceptual models and theories can influence and/or change scientific thought and lead to the development of new technologies;

F2. investigate special relativity and quantum mechanics, and solve related problems;

F3. demonstrate an understanding of the evidence that supports the basic concepts of quantum mechanics and Einstein's theory of special relativity.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 analyse the development of the two major revolutions in modern physics (e.g., the impact of the discovery of the photoelectric effect on the development of quantum mechanics; the impact of thought experiments on the development of the theory of relativity), and assess how they changed scientific thought [AI, C]

Sample questions: Which scientists made the most important contributions to the development of quantum mechanics? What kinds of experiments did they conduct? What sorts of discoveries did they make? In what ways did later discoveries build on earlier ones? What experiments and discoveries led to the development of the theory of relativity? What impact did Einstein's theories have on later scientific thought?

F1.2 assess the importance of relativity and quantum mechanics to the development of various technologies (e.g., nuclear power; light sensors; diagnostic tools such as magnetic resonance imaging [MRI], computerized axial tomography [CAT], positron emission tomography [PET]) [AI, C]

Sample questions: How has quantum computing moved the computer age forward? What are some of the applications of the theory of relativity and/or quantum mechanics in medicine? Why were quantum mechanics and the theory of relativity necessary to the development of the atomic bomb?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to quantum mechanics and special relativity, including, but not limited to: *quantum theory*, *photoelectric effect*, *matter waves*, *time dilation*, and *mass–energy transformation* [C]

F2.2 solve problems related to the photoelectric effect, the Compton effect, and de Broglie's matter waves [PR, AI]

F2.3 solve problems related to Einstein's theory of special relativity in order to calculate the effects of relativistic motion on time, length, and mass (e.g., the half-life of cosmic ray muons, how far into the future a fast space ship would travel, the magnetic field strength necessary to keep protons in the Large Hadron Collider) [PR, AI]

F2.4 conduct a laboratory inquiry or computer simulation to analyse data (e.g., on emission spectra, the photoelectric effect, relativistic momentum in accelerators) that support a scientific theory related to relativity or quantum mechanics [PR, AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 describe the experimental evidence that supports a particle model of light (e.g., the photoelectric effect, the Compton effect, pair creation, de Broglie's matter waves)

F3.2 describe the experimental evidence that supports a wave model of matter (e.g., electron diffraction)

F3.3 identify Einstein's two postulates for the theory of special relativity, and describe the evidence supporting the theory (e.g., thought experiments, half lives of elementary particles, relativistic momentum in accelerators, the conversion of matter into energy in a nuclear power plant)

F3.4 describe the standard model of elementary particles in terms of the characteristics of quarks, hadrons, and field particles

Physics, Grade 12

College Preparation SPH4C

This course develops students' understanding of the basic concepts of physics. Students will explore these concepts with respect to motion; mechanical, electrical, electromagnetic, energy transformation, hydraulic, and pneumatic systems; and the operation of commonly used tools and machines. They will develop their scientific investigation skills as they test 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

Big Ideas

Motion and Its Applications

- All motion involves a change in the position of an object over time.
- Motion can be described using mathematical relationships.
- Many technologies that utilize the principles of motion have societal and environmental implications.

Mechanical Systems

- Mechanical systems use force to do work.
- The operation of mechanical systems can be described using mathematical relationships.
- Friction is a force that influences the design, use, and effectiveness of mechanical systems.
- Mechanical systems can be used to address social and environmental challenges.

Electricity and Magnetism

- Relationships between electricity and magnetism are predictable.
- Electricity and magnetism have many technological applications.
- Technological applications that use electricity and magnetism can affect society and the environment in positive and negative ways.

Energy Transformations

- Energy can be transformed from one type to another.
- Systems that involve energy transformations are never 100% efficient.
- Although technological applications that involve energy transformations can affect society and the environment in positive ways, they can also have negative effects, and therefore must be used responsibly.

Hydraulic and Pneumatic Systems

- Fluids under pressure can be used to do work.
- Fluids under pressure have predictable properties and many technological applications.
- The uses of hydraulic and pneumatic systems can have social and economic consequences.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Motion and Its Applications	Mechanical Systems	Electricity and Magnetism	Energy Transformations	Hydraulic and Pneumatic Systems
Matter			✓		✓
Energy	✓	✓	✓	✓	
Systems and Interactions	✓	✓	✓	✓	✓
Structure and Function	✓	✓	✓	✓	✓
Sustainability and Stewardship		✓		✓	✓
Change and Continuity			✓	✓	✓

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., electronic probes, pendulums, cylinders) and materials (e.g., motion carts, magnets, simple machines), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection (e.g., personal protective equipment when carrying out fluids experiments)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems using quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., free-body diagrams, algebraic equations)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., alternative energy advocate, sustainable energy technician, electrician, mechanic) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Elijah McCoy, Jaisel Vadgama, Gerald Vincent Bull, Elizabeth Cannon, Richard Marceau, Normand C. Beaulieu), to the fields under study

B. MOTION AND ITS APPLICATIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse selected technologies that are used to move objects or track their motion, and evaluate their impact on society and the environment, including their contribution to scientific knowledge;

B2. investigate, in qualitative and quantitative terms, the linear uniform and non-uniform motion of objects, and solve related problems;

B3. demonstrate an understanding of different kinds of motion and the relationships between speed, acceleration, displacement, and distance.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 analyse the design and uses of a transportation technology (e.g., snowmobiles, automobiles, motorized personal water craft), and evaluate its social and environmental impact, including the impact on risk behaviour and accident rates [AI, C]

Sample issue: All-terrain vehicles (ATVs), designed to be driven off-road, are used in occupations requiring access to remote areas and for recreational purposes. However, ATVs can lack stability on uneven surfaces, which can result in serious accidents, particularly for inexperienced drivers. The vehicles can also cause damage when they are driven in environmentally sensitive areas.

Sample questions: What design aspects of the snowmobile make it particularly useful for travel over ice or snow? What impact does the altering of a vehicle's centre of gravity have on the functioning of the vehicle? Why is it important to take training courses before operating a motorized vehicle? Why are there special licences and training for different kinds of motor vehicles?

B1.2 analyse how technologies are used to track the motion of objects, and outline various kinds of scientific knowledge gained through the use of such technologies (e.g., data on animal populations and migrations, on changes in ocean currents related to global warming, on the behaviour of celestial objects) [AI, C]

Sample issue: In order to bill drivers for road use, a toll highway in southern Ontario uses motion cameras and transponders to track where vehicles enter and exit the highway. The information provided can also be used to analyse traffic flow and to determine when existing roads are unable to handle the volume of traffic.

Sample questions: How are motion-related technologies used to monitor wildlife populations? What type of information do these technologies provide, and how is it used? How are satellites used to track weather systems? What are the uses of the information gathered?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to motion, including, but not limited to: *distance, displacement, position, speed, acceleration, instantaneous, force,* and *net force* [C]

B2.2 plan and conduct investigations to measure distance and speed for objects moving in one dimension in uniform motion [IP, PR]

B2.3 plan and conduct investigations to measure constant acceleration for objects moving in one dimension [IP, PR]

B2.4 draw distance–time graphs, and use the graphs to calculate average speed and instantaneous speed of objects moving in one dimension [PR, AI, C]

B2.5 draw speed–time graphs, and use the graphs to calculate average acceleration and distance of objects moving in one dimension [PR, AI, C]

B2.6 solve simple problems involving one-dimensional average speed (v_{av}), distance (Δd), and elapsed time (Δt), using the algebraic equation $v_{av} = \Delta d/\Delta t$ [AI]

B2.7 solve simple problems involving one-dimensional average acceleration (a_{av}), change in speed (Δv), and elapsed time (Δt) using the algebraic equation $a_{av} = \Delta v/\Delta t$ [AI]

B2.8 plan and conduct an inquiry to determine the relationship between the net force acting on an object and its acceleration in one dimension [IP, PR, AI]

B2.9 analyse, in quantitative terms, the forces acting on an object, and use free-body diagrams to determine net force and acceleration of the object in one dimension [AI, C]

B2.10 conduct an inquiry to measure gravitational acceleration, and calculate the percentage error of the experimental value [PR, AI, C]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 distinguish between constant, instantaneous, and average speed, and give examples of each involving uniform and non-uniform motion

B3.2 describe the relationship between one-dimensional average speed (v_{av}), distance (Δd), and elapsed time (Δt)

B3.3 describe, in quantitative terms, the relationship between one-dimensional average acceleration (a_{av}), change in speed (Δv), and elapsed time (Δt)

B3.4 state Newton's laws, and apply them qualitatively and quantitatively to explain the motion of an object in one dimension

B3.5 explain the relationship between the acceleration of an object and the net unbalanced force acting on that object

C. MECHANICAL SYSTEMS

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse common mechanical systems that use friction and applied forces, and evaluate their effectiveness in meeting social or environmental challenges;

C2. investigate forces, torque, work, coefficients of friction, simple machines, and mechanical advantage, and interpret related data;

C3. demonstrate an understanding of concepts related to forces and mechanical advantage in relation to mechanical systems.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse advantages and disadvantages of friction within mechanical systems in real-world situations, as well as methods used to increase or reduce friction in these systems (e.g., advantages of, and methods for increasing, friction on the surface of car tires and the soles of hiking boots; disadvantages of, and methods for reducing, friction between moving parts of artificial joints) [AI, C]

Sample issue: Hip replacement has become an increasingly common surgical procedure. Artificial hips consist of separate pieces, made of low-friction materials, that are designed to mimic the movement of the ball and socket hip joint. As the artificial joint ages, however, wear debris can cause increasing friction and restrict movement in the joint.

Sample questions: What changes to the design of the bobsled have resulted in faster speeds in competition and improved steering and manoeuvrability? How and why does an under- or over-inflated tire affect the performance of a motor vehicle? Why do the soles of athletic shoes differ depending on the purpose of the shoe? Why do race car tires have no treads?

C1.2 evaluate, on the basis of research, the effectiveness of a common mechanical system in addressing a social or environmental challenge (e.g., prosthetic devices, bathtub lifts, high-efficiency heating and cooling systems) [IP, PR, AI, C]

Sample issue: In the nineteenth century, lift locks were built in Ontario to give boats access to unnavigable sections of waterways such as the Great Lakes and the Trent-Severn waterway. Although the locks were mechanically simple, they were also highly effective, and some continue to be used to the present day.

Sample questions: Why were crumple zones and airbags added to cars? How have integrated mechanical systems such as programmable thermostats improved energy efficiency in homes?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to mechanical systems, including, but not limited to: *coefficients of friction, torque, mechanical advantage, work input*, and *work output* [C]

C2.2 analyse, in qualitative and quantitative terms, the forces (e.g., gravitational, frictional, and normal forces; tension) acting on an object in one dimension, and describe the resulting motion of the object [AI, C]

C2.3 use an inquiry process to determine the factors affecting static and kinetic friction, and to determine the corresponding coefficient of friction between an everyday object and the surface with which it is in contact [PR, AI]

C2.4 use an inquiry process to determine the relationships between force, distance, and torque for the load arm and effort arm of levers [IP, PR, AI]

C2.5 solve problems involving torque, force, load-arm length, and effort-arm length as they relate to the three classes of levers [AI]

C2.6 investigate, in quantitative terms, common machines (e.g., a bicycle, a can opener, a piano) with respect to input and output forces and mechanical advantage [PR]

C2.7 construct a simple or compound machine, and determine its mechanical advantage (e.g., a pulley, a mobile, a can crusher, a trebuchet) [PR, AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 identify and describe, in quantitative and qualitative terms, applications of various types of simple machines (e.g., wedges, screws, levers, pulleys, gears, wheels and axles)

C3.2 explain the operation and mechanical advantage of compound machines and biomechanical systems (e.g., block-and-tackle, winch, chain-and-sprocket systems; the human leg, arm)

C3.3 explain, with reference to force and displacement, the conditions necessary for work to be done

C3.4 explain the concept of mechanical advantage

D. ELECTRICITY AND MAGNETISM

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse the development of selected electrical and electromagnetic technologies, and evaluate their impact on society and the environment;

D2. investigate real and simulated mixed direct current circuits and the nature of magnetism and electromagnetism, and analyse related data;

D3. demonstrate an understanding of the basic principles of electricity and magnetism.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 evaluate, on the basis of research, the impact on society and the environment of the evolution of an electrical technology (e.g., electric cars or buses, electric appliances) [IP, PR, AI, C]

Sample issue: Prior to the development of the electric light bulb, people used candles, gaslight, and oil lamps. After the tungsten filament was developed, incandescent light bulbs changed the way society used light, and resulted in increased demands for electrical power. Today, inefficient incandescent bulbs are increasingly being replaced by compact fluorescent bulbs.

Sample questions: What impact has the development and evolution of refrigeration technologies had on society and the environment? Are trains powered by electricity an improvement over trains powered by steam or diesel engines? Why or why not? What impact does the use of electric buses, streetcars, and subway trains by the Toronto Transit Commission have on local residents and the environment?

D1.2 assess the impact of an electromagnetic technology that is used for the benefit of society or the environment (e.g., devices for diagnosing and treating diseases, technologies for treating seeds to increase the rate of germination) [AI, C]

Sample issue: Globally, landmines cause thousands of deaths and injuries each year. Although many countries, including Canada, have signed an agreement banning the use of landmines, old mines continue to be a hazard. Specially trained personnel use electromagnetic technologies to detect and clear mines.

Sample questions: What impact has electromagnetic technology had on the usefulness and security of credit cards? What are some of the uses of electromagnetic technologies in health care? What are the benefits of using electromagnetic sensors to detect metal concentrations in brown-field developments? What are the advantages of maglev trains over conventional transportation technologies?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to electricity and magnetism, including, but not limited to: *direct current, alternating current, electrical potential difference, resistance, power, energy, permanent magnet, electromagnet, magnetic field, motor principle,* and *electric motor* [C]

D2.2 construct real and simulated mixed direct current (DC) circuits (i.e., parallel, series, and mixed circuits), and analyse them in quantitative terms to test Kirchhoff's laws [PR, AI]

D2.3 analyse, in quantitative terms, real or simulated DC circuits and circuit diagrams, using Ohm's law and Kirchhoff's laws [AI]

D2.4 conduct an inquiry to determine the magnetic fields produced by a permanent magnet, a straight current-carrying conductor, and a solenoid, and illustrate their findings [PR, AI, C]

D2.5 conduct an inquiry to determine the direction of the magnetic field of a straight current-carrying conductor or solenoid [PR, AI]

D2.6 conduct an inquiry to determine the direction of the forces on a straight current-carrying conductor that is placed in a uniform magnetic field [PR, AI]

D2.7 construct, or deconstruct and explain the components of, a basic electric device (e.g., a DC motor, a water-level detector) [PR, C]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 compare and contrast the behaviour and functions of series, parallel, and mixed DC circuits

D3.2 state Kirchhoff's laws and Ohm's law, and use them to explain, in quantitative terms, direct current, potential difference, and resistance in mixed circuit diagrams

D3.3 identify and explain safety precautions related to electrical circuits in the school, home, and workplace (e.g., the importance of turning off the current before performing electrical repairs; the reasons for grounding circuits; how to safely replace spent fuses; the use of double insulated tools and appliance circuit breakers)

D3.4 describe, with the aid of an illustration, the magnetic field produced by permanent magnets (bar and U-shaped) and electromagnets (straight conductor and solenoid)

D3.5 explain the law of magnetic poles

D3.6 distinguish between conventional current and electron flow

D3.7 state Oersted's principle, and apply the right-hand rule to explain the direction of the magnetic field produced when electric current flows through a long, straight conductor and through a solenoid

D3.8 state the motor principle, and use the right-hand rule to explain the direction of the force experienced by a conductor

D3.9 explain, using diagrams, the components and operation of a DC electric motor

D3.10 compare and contrast direct current and alternating current (AC) in qualitative terms (e.g., the difference between DC and AC motors), and describe situations in which each is used

E. ENERGY TRANSFORMATIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. evaluate the impact on society and the environment of energy-transformation technologies, and propose ways to improve the sustainability of one such technology;

E2. investigate energy transformations and the law of conservation of energy, and solve related problems;

E3. demonstrate an understanding of diverse forms of energy, energy transformations, and efficiency.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse an energy-transformation technology (e.g., wind turbines, refrigerators, telephones, steam engines, coal-fired electrical plants), and evaluate its impact on society and the environment [AI, C]

Sample issue: Fax machines allow documents to be transmitted quickly and securely. Most fax machines use ink cartridges, which can end up in landfill sites. By contrast, thermal fax machines use heat resistors to convert electricity into usable heat. They then apply this heat through a print head onto chemically treated paper to print a document.

Sample questions: What types of energy transformations take place in an air conditioner? What impact does the widespread use of air conditioners have on society and the environment? What types of energy transformations occur in incandescent and fluorescent light bulbs? What impact does the difference in energy transformations in these two types of bulbs have on the environment?

E1.2 propose a course of practical action to improve the sustainability of an energy-transformation technology (e.g., solar panels, internal combustion engines, fuel cells, air conditioners) [PR, AI, C]

Sample issue: Although wind is a renewable source of energy, many windmills are needed to generate a useful amount of energy, and large wind farms can have a negative impact on wildlife and local residents. Researchers are experimenting with modifications to the blades to increase the efficiency of each windmill.

Sample questions: Why are ice-cooling systems more energy efficient than traditional air conditioners? How could solar panels be modified to enable them to capture solar energy on a cloudy day? How could a speaker system be improved to maximize its energy use? What modifications could be made to an internal combustion engine so that it used less gasoline?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to energy and energy transformations, including, but not limited to: *work*, *gravitational potential energy*, *kinetic energy*, *chemical energy*, *energy transformations*, and *efficiency* [C]

E2.2 use the law of conservation of energy to solve problems involving gravitational potential energy, kinetic energy, and thermal energy [AI]

E2.3 construct a simple device that makes use of energy transformations (e.g., a pendulum, a roller coaster), and use it to investigate transformations between gravitational potential energy and kinetic energy [PR]

E2.4 design and construct a complex device that integrates energy transformations (e.g., a mousetrap vehicle, an "egg-drop" container, a wind turbine), and analyse its operation in qualitative and quantitative terms [IP, PR, AI]

E2.5 investigate a simple energy transformation (e.g., the use of an elastic band to propel a miniature car), explain the power and output, and calculate the energy [PR, AI, C]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe and compare various types of energy and energy transformations (e.g., transformations related to kinetic, sound, electric, chemical, potential, mechanical, nuclear, and thermal energy)

E3.2 explain the energy transformations in a system (e.g., a toy, an amusement park ride, a skydiver suspended from a parachute), using principles related to kinetic energy, gravitational potential energy, conservation of energy, and efficiency

E3.3 describe, with the aid of diagrams, the operation of selected energy-transformation technologies (e.g., wind turbines, photoelectric cells, heat engines)

E3.4 compare the efficiency of various systems that produce electricity (e.g., wind farms, hydroelectric generators, solar panels), using the law of conservation of energy, and outlining the transformations, transmissions, and energy losses involved

E3.5 describe a variety of renewable and non-renewable sources of energy (e.g., solar energy, fossil fuels, hydroelectric energy, energy generated from biomass), and identify the strengths and weaknesses of each

F. HYDRAULIC AND PNEUMATIC SYSTEMS

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse the development of technological applications related to hydraulic and pneumatic systems, and assess some of the social and environmental effects of these systems;

F2. investigate fluid statics, fluid dynamics, and simple hydraulic and pneumatic systems;

F3. demonstrate an understanding of the scientific principles related to fluid statics, fluid dynamics, and hydraulic and pneumatic systems.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 research the historical development of a pneumatic or hydraulic system used in a specific technology (e.g., the hydraulic system in aircraft or other vehicles or in precision machining; the pneumatic system in an air motor or robotics), analyse the original design, and determine why the technology was developed and how it has been improved [IP, PR, AI, C]

Sample questions: How have hydraulic systems in aircraft improved over the past 50 years? In what ways have pneumatic systems been used to improve the ergonomics of workplace equipment? In what ways have the uses of hydraulic systems for irrigation purposes evolved over time?

F1.2 analyse some of the social and economic consequences of the use of robotic systems for different kinds of operations (e.g., in the manufacturing of computers, for lifting and manoeuvring heavy objects on assembly lines, for handling hazardous materials, for activities under water and in space) [AI, C]

Sample issue: The use of robotic systems on assembly lines in automotive plants speeds up production, cuts labour costs, reduces the need for workers to perform small repetitive tasks, and reduces workplace injuries. But the use of such systems has eliminated some jobs.

Sample questions: What impact could remote surgery using robotics have on the health of people living in remote areas? What types of jobs are made safer through the use of robotics? How can simulations using robotics reduce the social and economic costs associated with natural disasters?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to hydraulic and pneumatic systems, including, but not limited to: *density, atmospheric pressure, absolute pressure, laminar flow, turbulent flow, static pressure, pressure, volume,* and *flow rate* [C]

F2.2 draw simple hydraulic or pneumatic circuits [C]

F2.3 use an inquiry process to determine factors that affect the static pressure head in fluids, compare theoretical and empirical values, and account for discrepancies [IP, PR, AI]

F2.4 conduct a laboratory inquiry or computer simulation to demonstrate Pascal's principle [PR]

F2.5 use an inquiry process to determine the relationships between force, area, pressure, volume, and time in a hydraulic or pneumatic system (e.g., a hydraulic bottle rocket, a two-cylinder circuit using small plastic syringes filled with air or water) [IP, PR, AI]

F2.6 solve problems related to the relationships between force, area, pressure, volume, and time in hydraulic and pneumatic systems (e.g., the force exerted on the wheel of a motor vehicle by the hydraulically operated brake pad; the time required for a robotic system to complete one cycle of operation) [AI]

F2.7 design and construct a hydraulic or pneumatic system (e.g., a braking system for a car, a clamping device, a model of a crane), solving problems as they arise, and evaluate the system with respect to mechanical advantage and efficiency [IP, PR, AI]

F2.8 conduct an inquiry to demonstrate Bernoulli's principle (e.g., using a wind tunnel or Venturi tube, suspending a table tennis ball in an air current, blowing between pieces of paper) [PR]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 identify factors affecting static pressure head (e.g., variations in Earth's atmosphere), analyse static pressure head in quantitative terms, and explain its effects in liquids and gases

F3.2 state Pascal's principle, and explain its applications in the transmission of forces in fluid systems

F3.3 describe common components used in hydraulic and pneumatic systems (e.g., cylinders, valves, motors, fluids, hoses, connectors, pumps, reservoirs), and explain their function

F3.4 describe factors affecting laminar flow, and explain how the design of an item or organism (e.g., cars, boats, planes, turbine blades, propellers, golf balls, swimsuits, sharks) responds to these factors

F3.5 state Bernoulli's principle, and explain some of its applications (e.g., spray atomizers, propellers, spoilers on racing cars, turbine blades in jet engines)

SCIENCE

Science, Grade 12

University/College Preparation **SNC4M**

This course enables students, including those pursuing postsecondary programs outside the sciences, to increase their understanding of science and contemporary social and environmental issues in health-related fields. Students will explore a variety of medical technologies, pathogens and disease, nutritional science, public health issues, and biotechnology. The course focuses on the theoretical aspects of the topics under study and helps refine students' scientific investigation skills.

Prerequisite: Science, Grade 10, Academic, or any Grade 11 university, university/college, or college preparation course in science

Big Ideas

Medical Technologies

- Medical technologies can have positive and negative effects on society, human health, the economy, and the environment.
- Knowledge of medical technologies, and the science behind them, can help patients better understand their diagnoses and treatment options.

Pathogens and Disease

- Appropriate technologies and informed choices with respect to personal behaviour can limit the spread of pathogens and diseases.
- Methods used to control the spread of pathogens and diseases can have both positive and negative effects on human health.

Nutritional Science

- The nutrients and other substances found in foods affect human health and well-being.
- An understanding of the role of nutrients and other substances found in foods enables people to make healthy lifestyle choices.

Science and Public Health Issues

- An understanding of threats to public health helps individuals and societies adopt appropriate practices to protect their health and the health of others.
- A global approach to public health is necessary to help prevent future pandemics.

Biotechnology

- Many social, ethical, and legal issues and conflicting interests have to be considered when determining the appropriate uses of biotechnology.
- Scientific knowledge helps individuals and society make informed decisions regarding biotechnology.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Medical Technologies	Pathogens and Disease	Nutritional Science	Science and Public Health Issues	Biotechnology
Matter	✓	✓	✓		✓
Energy	✓		✓		
Systems and Interactions		✓	✓	✓	
Structure and Function	✓	✓			
Sustainability and Stewardship			✓		✓
Change and Continuity		✓		✓	✓

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., respirometer, titration apparatus) and materials (e.g., prepared slides, Petri dishes, food samples), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials, including biological waste (e.g., techniques to prevent contamination of specimens); and by using appropriate personal protection (e.g., wearing gloves when handling biological specimens)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., nuclear medicine technician, nurse practitioner, hematologist, dietitian, geneticist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Frederick Banting, John A. Hopps, Louis Siminovitch, Jean Cuthand Goodwill, Nancy Olivieri), to the field under study

B. MEDICAL TECHNOLOGIES

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. assess the impact of medical technologies and therapies, both conventional and alternative, used to diagnose and treat human health conditions;

B2. investigate the uses of, and analyse the information provided by, a variety of medical technologies;

B3. demonstrate an understanding of the function and use of a variety of medical technologies and the information they provide about the human body.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 assess the costs and benefits of a conventional medical technology, therapy, or device that is used to diagnose or treat a human health condition (e.g., diagnostic technologies such as X-rays and ultrasound; surgical procedures such as laser removal of tumours; biomedical devices such as prosthetics) [AI, C]

Sample issue: Reproductive technologies have permitted many infertile couples to have babies. However, treatments can be expensive, and the long-term effects of strong hormone therapies that accompany in vitro fertilization are unknown. Moreover, some cultures routinely use these technologies for sex selection, resulting in skewed sex ratios and accompanying social problems.

Sample questions: What are the benefits of using nuclear isotopes in the diagnosis of disease? What are the costs of this technology, including the potential long-term health effects for patients? What are the benefits of organ transplants? Why is there a black market in human organs, and what can be done to stop it? What are the benefits of telesurgery for people living in remote areas?

B1.2 identify a variety of alternative technologies and therapies used to diagnose or treat human health conditions (e.g., biofeedback, acupuncture, homeopathy, chiropractic, Aboriginal healing practices), and assess the effectiveness of one such therapy [AI, C]

Sample issue: Naturopathic medicine focuses on the ability of the body to heal and maintain itself. Practitioners emphasize a holistic approach to health and use herbal medicines and non-invasive treatments. However, there is a lot of controversy over the effectiveness of some herbal treatments and proposals for their regulation.

Sample questions: How effective are botanical treatments for skin irritations? What are their limitations? How does acupuncture work? What sort of ailments is it used to treat? How effective is it? What is biofeedback? What sorts of conditions does it treat effectively? What are its limitations?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to medical technologies, including, but not limited to: *aseptic techniques*, *feedback loop*, *biochemical*, and *biomechanical* [C]

B2.2 use a variety of medical technologies to collect data related to blood pressure, heart rate, lung capacity, and body mass, and analyse the data (e.g., use a stethoscope to determine heart rate under various conditions; use a respirometer to measure lung capacity) [PR, AI]

B2.3 use a microscope to investigate prepared slides of human blood, identifying blood cells by type, size, and number, and determine the ratios between different cells in the samples [PR, AI]

B2.4 interpret information generated by a variety of imaging technologies (e.g., X-rays, ultrasound), and communicate their findings [AI, C]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 explain the four primary vital signs in humans (i.e., body temperature, heart rate, blood pressure, respiration rate)

B3.2 describe the normal range for various physiological and biochemical indicators (e.g., heart rate, lung capacity, blood pressure, blood sugar)

B3.3 explain the function and use of a variety of medical devices and technologies for diagnostic and treatment purposes (e.g., sphygmomanometer, stethoscope, ultrasound, X-ray, computerized axial tomography [CAT] scan, pacemaker, chemotherapy)

B3.4 describe the function and use of technologies, devices, and techniques for biomedical repair (e.g., prosthetics, artificial organs, plastic surgery)

B3.5 describe a recent technological development or advance in diagnosis or treatment in the health care field (e.g., artificial skin for burn victims, artificial and transgenic organ transplants, smart drugs, nanotechnologies, biophotonics)

C. PATHOGENS AND DISEASE

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. evaluate the impact of scientific and technological knowledge and individual behaviour on the control of pathogens and the prevention of disease;

C2. investigate the nature and growth of pathogens and the effectiveness of measures intended to prevent their spread;

C3. demonstrate an understanding of pathogens, the diseases they cause, and ways of controlling their spread.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse, on the basis of research, the impact, both positive and negative, of scientific and technological advances intended to prevent the spread of illness and disease [IP, PR, AI, C]

Sample issue: The development of antibiotics such as penicillin and sulfa in the twentieth century saved many lives. However, overuse and improper use of antibiotics have contributed to the development of antibiotic-resistant forms of bacteria that threaten public health.

Sample questions: How does the irradiation of food reduce the incidence of food-borne illness? Why is the use of this technology controversial? What are the pros and cons of using insecticides such as DDT to kill malaria-carrying mosquitoes? What are the advantages and disadvantages of using "no touch" technologies to stem the spread of diseases?

C1.2 evaluate the impact of individual choices (e.g., with respect to vaccination, the proper use of antibiotics or mosquito repellent) on the control of pathogens and the prevention of disease [AI, C]

Sample issue: Intravenous drug users who share needles risk transmitting or contracting serious diseases such as hepatitis and HIV/AIDS. Programs such as needle exchanges and safe injections sites reduce the risks posed by shared needle use, but their success depends on the initiative of the drug users.

Sample questions: What measures should food handlers take to prevent the spread of disease? What precautions should travellers take in order not to spread disease? Why is it important to stay home when you have a communicable illness?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to pathogens and diseases, including, but not limited to: *parasite, epidemiology, pathogenesis,* and *vector* [C]

C2.2 analyse, on the basis of inquiry, the effects of various treatments on pathogenesis (e.g., the effect of mouthwash or penicillin on the growth of bacteria) [PR, AI]

C2.3 analyse, using prepared slides or computer simulations, the characteristics, properties, and virulence of various bacteria [PR, AI]

C2.4 use an inquiry process to demonstrate the effect of the use of sterile techniques (e.g., pasteurization, use of an autoclave) on pathogenesis [IP, PR]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 describe the characteristics and life cycles, including reproductive cycles, of representative pathogens (e.g., lysogenic cycle; lytic cycle; infectious cycle of malaria)

C3.2 describe the mode of transmission of various diseases, including those that are insect-borne (e.g., malaria, encephalitis), airborne (e.g., influenza, tuberculosis), water-borne (e.g., cholera, poliomyelitis), sexually transmitted (e.g., HIV/AIDS), and food-borne (e.g., mad cow disease, trichinosis, salmonella)

C3.3 explain how the human immune response acts as a natural defence against infection

C3.4 describe the role of vaccines, antibiotics, antiretrovirals, and other drug therapies and antiseptics in the control of pathogenesis

C3.5 describe non-medical ways to protect oneself from contracting pathogenic disease in a variety of situations (e.g., aseptic techniques such as wearing sterile gloves; proper personal hygiene such as frequent and thorough hand washing; the use of insect repellent)

C3.6 describe some of the means used by international non-governmental organizations (e.g., Médecins sans Frontières, Oxfam, Ryan's Well Foundation, UN agencies, the Stephen Lewis Foundation) to control the spread of disease (e.g., distribution of vaccines, medication, malaria nets; installing wells so people have access to clean water; public education on strategies for transmission prevention)

C3.7 describe aseptic techniques used in the workplace, and explain their importance in preventing the spread of pathogens (e.g., cooking meat to a safe temperature and refrigerating leftovers quickly to avoid growth of bacteria in restaurant food; frequent hand sanitizing and use of sterile gloves in hospitals to prevent the spread of pathogens to vulnerable populations)

D. NUTRITIONAL SCIENCE

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. assess how personal and societal factors affect eating behaviours, and evaluate the social and economic impact of the use of non-nutrient food additives;

D2. investigate chemical components of and energy in food, and the processes by which food is digested;

D3. demonstrate an understanding of chemical components of and energy in food, and the processes by which food is digested.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 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., sulfites in dried fruit; food colouring; MSG) [AI, C]

Sample issue: Non-nutrient food additives increase the shelf life of many foods, decreasing waste from spoiled food and allowing foods to be transported around the globe. Importing food increases consumer choice, yet it also increases carbon emissions and can hurt the Canadian farm economy.

Sample questions: What types of additives are used to make vegetables in salad bars and grocery stores stay green and fresh looking? How do these additives benefit the retailer? What effect do they have on consumers? Why are nitrates added to many types of processed meat? What sorts of foodstuffs contain artificial colour? What health risks are associated with these additives?

D1.2 evaluate the impact of some personal and societal factors (e.g., allergies, disease, body image, cultural preferences) on eating behaviours (e.g., the relationship between societal ideals of beauty and interest in "fad" diets) [AI, C]

Sample issue: A nutritious diet is an important component of a healthy lifestyle. Yet, decisions about what to eat can be influenced by social factors such as the availability of fast food in a fast-paced society, peer pressure, and the pervasive images presented by the fashion and entertainment industries.

Sample questions: What effect does advertising have on your food choices? How do food allergies affect the diets of individuals and the food choices available in school cafeterias? Why do people with diabetes have to monitor their consumption of sugar and carbohydrates? What impact does anorexia have on a person's eating behaviours? What effect can a person's cultural background have on their food choices?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to nutritional science, including, but not limited to: *macromolecules*, *protein*, *starch*, *vitamin*, *carbohydrate*, *fats*, *lipids*, *pepsin*, and *amylase* [C]

D2.2 plan and conduct chemical tests on a variety of foods to determine their chemical components (e.g., protein, starch, fats, lipids, carbohydrates, vitamins) [IP, PR, AI]

D2.3 investigate how enzymes break down macromolecules (e.g., amylase digests starch; pepsin and hydrochloric acid digest protein), and test the products of different types of digestion (e.g., use Benedict's solution to test for the presence of simple sugars produced by the digestion of carbohydrates) [PR]

D2.4 investigate the process of emulsification in fats and lipids (e.g., using commercially obtained bile and cooking oil) [PR]

D2.5 conduct titrations to determine the effects of various antacids on hydrochloric acid [PR, AI]

D2.6 plan and conduct an inquiry to determine the nutrient or energy content in selected food samples (e.g., hamburger, bread) [IP, PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 describe the basic chemical components of proteins, carbohydrates, fats and lipids, and vitamins and minerals, and explain their functions in the body

D3.2 explain how laboratory methods are used to determine the relative energy content of food (e.g., use of a calorimeter)

D3.3 describe requirements for a balanced diet based on the biochemical and energy needs of the average body, and explain how these requirements might vary among people with different lifestyles (e.g., young children, the elderly, a person with diabetes, an athlete)

D3.4 describe the structure and function of the components of the digestive system (e.g., mouth, tongue, epiglottis, esophagus, stomach, intestines, liver, gall bladder, pancreas, appendix, rectum, anus, salivary glands, saliva, bile) with respect to physical and chemical digestion

D3.5 describe optimum conditions for the effective functioning of some digestive enzymes found within the human body (e.g., amylase, pepsin)

E. SCIENCE AND PUBLIC HEALTH ISSUES

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. assess the impact of scientific research, technological advances, and government initiatives on public health;

E2. investigate various strategies related to contemporary public health issues;

E3. demonstrate an understanding of major public health issues, past and present.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 assess the impact of scientific research and technological advances on public health around the world (e.g., widespread immunization for diseases such as polio, telemedicine for people in remote areas, new drug therapies to combat disease) [AI, C]

Sample issue: In developed countries, people living with HIV/AIDS have access to highly effective but expensive drugs, which most people in the developing world cannot afford. Although patent restrictions have prevented the widespread use of cheaper generic drugs, some of these restrictions have recently been relaxed, which may decrease the global death toll from AIDS.

Sample questions: How are monitoring and reporting technologies used to contain the spread of infectious diseases such as avian flu and severe acute respiratory syndrome (SARS)? How effective is the use of mosquito nets in reducing the spread of malaria?

E1.2 assess, on the basis of research, the effectiveness of a municipal, provincial, or federal government initiative intended to protect the public health of Canadians (e.g., immunization programs, smoking bans, Health Canada advisories) [IP, PR, AI, C]

Sample issue: The Canadian Food Inspection Agency is responsible for administering laws that regulate agriculture and the food-processing industry. Its mandate includes monitoring farm animals for avian flu and mad cow disease and ensuring the safety of food additives. Although agency regulations have made food safer, each year many Canadians contract food-borne illnesses.

Sample questions: How effective have the safety measures for blood donation and transfusions been in reducing the spread of blood-borne diseases since the tainted-blood scandal of the 1980s? What is the impact on immunization programs of claims that vaccinations can cause severe side effects? How useful is the information on emergency preparedness and response in your local area?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to public health issues, including, but not limited to: *pandemic, contamination, infectious disease, quarantine,* and *vaccination* [C]

E2.2 analyse and interpret, using a case study or research data, scientific evidence regarding the effectiveness of a public health program intended to reduce disease transmission (e.g., distribution of bed nets to fight malaria; safe injection sites for intravenous drug users; programs to encourage hand washing in hospitals to stop the spread of C. difficile) [AI, C]

E2.3 use a research process to investigate public health strategies developed to combat a potential pandemic (e.g., SARS, C. difficile, avian flu) [IP, PR]

E2.4 use a research process to locate a media report on a public health issue (e.g., the handling of SARS, the banning of bisphenol-A in plastic bottles), summarize its arguments, and assess them from a scientific perspective [IP, PR, AI, C]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe the characteristics according to which a pandemic is classified (e.g., the strain of a virus, its mode of transmission)

E3.2 explain how pandemics have affected humanity throughout history (e.g., the bubonic plague of 1347–1352 in Europe, the cholera pandemic of 1817–1823 in Asia, the global Spanish influenza pandemic of 1918–1920, the contemporary AIDS pandemic)

E3.3 explain the impact of various threats to public health, including infectious diseases (e.g., hepatitis, HIV/AIDS, tuberculosis, malaria, sexually transmitted diseases), chronic diseases (e.g., cardiovascular disease, diabetes, asthma), and environmental factors (e.g., climate change, air pollution, chemical pollutants, radiation)

E3.4 explain a variety of social factors that can promote the rapid spread of infectious diseases (e.g., global population growth, international travel, poor sanitation, lack of clean drinking water)

E3.5 describe public health measures, including legislation, that are used for the protection of the public (e.g., quarantines, vaccinations, water chlorination, regulations on what items travellers can bring into a country)

E3.6 explain why some populations are particularly susceptible to specific health problems (e.g., the risk of diabetes among First Nations populations; the risk of thalassemia among Mediterranean populations; the risk of pneumonia and tuberculosis among people with HIV/AIDS)

F. BIOTECHNOLOGY

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse a variety of social, ethical, and legal issues related to applications of biotechnology in the health, agricultural, or environmental sector;

F2. investigate various techniques used in biotechnology and how they are applied in the food industry and the health and agricultural sectors;

F3. demonstrate an understanding of biological processes related to biotechnology and of applications of biotechnology in the health, agricultural, and environmental sectors.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 analyse social issues related to an application of biotechnology in the health, agricultural, or environmental sector (e.g., issues related to the uses of genetically modified organisms or to the uses and availability of in vitro fertilization) [AI, C]

Sample issue: The promise of genetically modified (GM) crops was that they would be resistant to pests and would produce more abundant harvests. However, GM crops can crossbreed with crops in adjoining fields, thus contaminating traditional food sources, reducing biodiversity, changing farming practices, and limiting the choices available to consumers.

Sample questions: What was the social impact of the discovery of insulin? What is the potential impact on the family of biotechnological developments related to the treatment of infertility and the genetic screening of embryos? What are the social benefits of the development of drought-resistant crops?

F1.2 analyse, on the basis of research, ethical and legal issues related to an application of biotechnology in the health, agricultural, or environmental sector (e.g., ethical questions related to xenotransplantation; legal issues related to access to an individual's genetic information) [IP, PR, AI, C]

Sample issue: Advances in biotechnological research in human health have raised many difficult questions. Currently, scientists, ethicists, politicians, and business people are debating issues such as who should have access to a person's genetic information, whether human cloning should be permitted, and whether human embryos should be used for stem-cell research.

Sample questions: If a disease has no known cure, should we use biotechnology to predict or diagnose its occurrence in individuals? Why or why not? Who owns or controls frozen embryos left over after in vitro fertilization? Who determines whether genetically modified foods are safe? How might the testing/regulation process be open to abuse? What are the legal and ethical implications of introducing into an ecosystem a species engineered through biotechnology?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to biotechnology, including, but not limited to: *selective breeding*, *hybridization*, *replication*, *mutation*, *genomics*, and *gene therapy* [C]

F2.2 plan and conduct an inquiry into various traditional biotechnological techniques used in the food industry (e.g., the use of fermentation to produce bread, cheese, yogurt) [IP, PR]

F2.3 investigate, through laboratory inquiry or computer simulation, a recently developed biotechnological method used in the health sector (e.g., the process of electrophoresis to degrade DNA) [PR]

F2.4 investigate, through laboratory inquiry or computer simulation, a recently developed biotechnological method used in the field of agriculture (e.g., bioremediation of a chemical fertilizer spill; the cloning of corn; the use of synthetic hormones to promote growth in livestock) [PR]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 explain various methods used, over time, in the field of biotechnology (e.g., use of living organisms to make or modify products, selective breeding to create particular breeds of animals, manipulation of genes to develop organisms with particular traits)

F3.2 explain the structure and functions of macromolecules (e.g., DNA, RNA) and the synthesis of proteins (e.g., transcription, translation, gene expression)

F3.3 describe applications of biotechnology in the health (e.g., genomics, gene therapy, xenotransplantation, in vitro fertilization), agricultural (e.g., genetically modified crops, biopesticides, cloning), and environmental sectors (e.g., bioremediation, phytoremediation)

Science, Grade 12

Workplace Preparation SNC4E

This course provides students with fundamental science knowledge and workplace skills needed to prepare them for success beyond secondary school. Students will explore hazards in the workplace, chemicals in consumer products, disease and its prevention, electricity at home and at work, and nutritional science. Emphasis is placed on current topics in science and relevant, practical activities that develop students' literacy and mathematical literacy skills and enhance their scientific literacy.

Prerequisite: Science, Grade 10, Applied, or a Grade 10 locally developed compulsory credit (LDCC) course in science

Big Ideas

Hazards in the Workplace

- Knowledge and understanding of science enable people to identify, explain, and minimize hazardous situations in the workplace.

Chemicals in Consumer Products

- Physical and chemical properties of chemicals determine how they can be used in consumer and industrial products.
- Incorrect handling and disposal of chemicals can lead to unsafe conditions in the home and the workplace and can harm the environment.

Disease and Its Prevention

- The spread of communicable diseases can be reduced through personal choices and the use of appropriate technologies.
- Methods used to control the spread of diseases can have both positive and negative effects.

Electricity at Home and Work

- Electrical equipment can pose a safety hazard in the home and workplace if it is not used correctly.
- Rapid advances in electronics, and consumers' desire for the latest electronics technology, have resulted in serious waste disposal problems.

Nutritional Science

- The nutrients and other substances found in food products have effects on human health and well-being.
- Knowledge of the role of nutrients and other substances found in food products enables people to make healthy lifestyle choices.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Hazards in the Workplace	Chemicals in Consumer Products	Disease and Its Prevention	Electricity at Home and Work	Nutritional Science
Matter		✓	✓		✓
Energy				✓	✓
Systems and Interactions	✓		✓	✓	
Structure and Function			✓	✓	
Sustainability and Stewardship	✓	✓	✓	✓	
Change and Continuity			✓		

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., a decibel meter, spot plates, glassware, thermometers) and materials (e.g., a heat lamp, agar plates, circuit boards), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., chemical technician, baker, blood laboratory assistant, custodian, public works employee, cosmetologist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Lorne Trottier, David Butler-Jones, Francine Décary, Robert G.E. Murray, Susan Barr), to the fields under study

B. HAZARDS IN THE WORKPLACE*

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. assess common workplace settings with respect to hazards, and analyse selected legislation that is in place to protect workers and the environment from these hazards;

B2. investigate the nature of workplace hazards and various ways in which workers can protect themselves from these hazards;

B3. demonstrate an understanding of common biological, chemical, and physical workplace hazards.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 assess a workplace setting, either real or simulated, with respect to hazards that could affect workers or the environment, using appropriate criteria (e.g., a checklist for a health and safety audit) [AI, C]

Sample issue: An employee has been asked to clean out the oil fryer at the restaurant where he works. He knows from his training that the fryer must cool down first, but the manager is rushing the clean-up crew to avoid having to pay them overtime.

Sample questions: What hazardous substances are used in the workplace being assessed? Are warnings posted as to the dangers they pose? How are the substances handled, stored, and disposed of? Are these practices safe? How might they be improved?

B1.2 analyse and summarize the requirements of selected sections of workplace safety and/or environmental protection legislation related to a career of personal interest (e.g., regulations applying to mining in the Occupational Health and Safety Act; regulations applying to waste management in the Ontario Environmental Protection Act) [AI, C]

Sample issue: Section 91.1 of the Ontario Environmental Protection Act requires employers to prevent or reduce the risk of spills of pollutants and, if such a spill does occur, to provide the appropriate equipment, personnel, and material to clean it up. This section covers a range of workplaces where spills of environmental contaminants may occur.

Sample questions: What types of jobs are affected by regulations under the Ontario Environmental Protection Act? What types of workers are covered by the Canada Labour Code? What changes did Bill C-45 make to the Canadian Criminal Code? Why? What is the purpose of the Ontario Needle Safety Regulation under the Occupational Health and Safety Act? What measures are in place in Ontario to protect workers from violence and harassment on the job?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to hazards in the workplace, including, but not limited to: *occupational exposure limits (OEL)*, *designated substance regulation (DSR)*, *personal protective equipment (PPE)*, *route of entry*, *controlled product*, *infectious material*, *inhalation*, *absorption*, *ingestion*, *injection*, and *exposure values* [C]

B2.2 plan and conduct an inquiry to determine what factors affect rates of chemical reactions (e.g., the concentration of an acid affects its rate of reaction with metals) [IP, PR, AI]

* Activities related to the achievement of expectations that refer to "the workplace" and/or that involve hazardous materials may be simulated in the classroom. It is the teacher's responsibility to ensure students' safety.

B2.3 investigate the effectiveness of methods used to reduce the impact of noise in the workplace (e.g., use a decibel meter to measure noise level before and after the installation of sound insulation; measure the effectiveness of earplugs at different sound levels) [PR]

B2.4 investigate the effects of workers' exposure to heat or cold (e.g., the effects of industrial heat sources such as molten materials on workers in foundries and factories; the effects of seasonal heat and cold, including exposure to solar radiation, on outdoor workers in construction, landscaping, agriculture, or hydro line repair; the effects of cold on workers in refrigerated warehouses) [PR]

B2.5 use a research process to investigate procedures for the safe handling of biohazardous and/or infectious materials in the workplace, and communicate their findings (e.g., create a webpage on the universal precautions for handling biological hazards; create a poster illustrating the steps for proper hand washing) [IP, PR, C]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 describe the ways in which hazardous materials enter the body (i.e., ingestion, inhalation, absorption, and injection), and explain the importance of using personal protective equipment (e.g., gloves, appropriate eye wear, aprons, self-contained breathing apparatus) to avoid contamination

B3.2 identify common physical hazards in the workplace (e.g., hazards posed by noise; cutting tools; electrical power lines; extreme heat and cold), and describe potentially harmful situations and practices (e.g., work at heights on unstable equipment) as well as best safety practices (e.g., properly securing ladders and scaffolding) relating to these hazards

B3.3 identify common biological hazards in the workplace (e.g., bacteria, viruses, fungi), and describe potentially harmful situations and practices (e.g., improper disposal of syringes) as well as best safety practices (e.g., use of PPE such as gloves and masks) relating to these hazards

B3.4 identify common chemical hazards in the workplace (e.g., oxidizers, acid and base solutions), and describe potentially harmful situations and practices (e.g., inadequate venting of fine dust particles in flour mills) as well as best safety practices (e.g., wearing goggles and a self-contained breathing apparatus when working near substances that can irritate the eyes or lungs) relating to these hazards

B3.5 describe ways in which workers can address safety issues in the workplace (e.g., by reporting an unsafe condition to a supervisor; by refusing unsafe work)

B3.6 explain qualitatively how factors such as temperature, concentration, and the size of the opening of a container affect storage and disposal of chemicals in the workplace

C. CHEMICALS IN CONSUMER PRODUCTS

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse chemical products used in the home and workplace, and issues related to their safe and environmentally responsible use and disposal;

C2. investigate chemical properties of, and chemical reactions used to produce, various consumer products;

C3. demonstrate an understanding of chemical reactions, and of properties of chemicals used in common household and workplace products.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 analyse, on the basis of research, a chemical product used in a particular profession or in the home (e.g., pool chemicals, chlorine bleach, hair dye), and prepare guidelines for safe and responsible use of the product [IP, PR, AI, C]

Sample issue: Bathroom cleaners need to be strong enough to kill germs and remove stains, but such requirements often mean that these products contain chemicals that can burn the skin and the irritate the eyes. What do people need to know about the precautions that should be taken when using such products?

Sample questions: What chemicals are in hair dye? How should hair stylists protect themselves and their clients from the harmful effects of these chemicals? What precautions must be taken when using solvents or bleaches? Why?

C1.2 assess the environmental consequences of improper disposal of chemical products commonly used in the home (e.g., pouring paint down the drain; dumping batteries in garbage destined for landfill sites) [AI, C]

Sample issue: Some batteries contain lithium or cadmium, which are toxic heavy metals. If such batteries are tossed into the regular garbage, these metals can leach into the soil or run off into water systems. Batteries can also overheat and cause a fire or other kind of chemical reaction.

Sample questions: What happens when pharmaceuticals are poured down the drain? Why should containers of flammable substances such as turpentine or corrosive substances such as drain cleaner not be thrown in the regular garbage?

C1.3 evaluate the appropriateness of current disposal practices in their home, at school, or in the community, with particular reference to the disposal of chemical waste [AI, C]

Sample issue: Many commonly used chemicals can damage the environment if they are not properly disposed of. Some chemicals are combustible, produce toxic vapours, or are corrosive. Some otherwise safe chemicals can become toxic if combined with another chemical. Safe disposal methods must take the properties of each chemical into account.

Sample questions: What is the proper method for disposing of solvent-soaked rags? What sorts of items are considered to be household hazardous waste (HHW)? Are there HHW depots in your community? What happens to the waste once it arrives at such a depot?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology relating to chemical reactions and chemical products, including, but not limited to: *synthesis, decomposition, neutralization, polymerization, combustion, single and double displacement, pH, solvent, organic, inorganic,* and *dilution* [C]

C2.2 use an inquiry process to determine how various conditions affect a chemical reaction, by altering the conditions under which a reaction occurs (e.g., temperature, length of time, amount of reactants, pH of a solution), observing the effects of the alterations, and comparing the outcome and final product of each reaction (e.g., make borax slime, then alter the proportion of the ingredients and measure the impact on properties of the product) [IP, PR, AI]

C2.3 prepare dilutions using concentrated solutions, and observe or measure the changes in properties (e.g., pH, colour, viscosity, density) [PR]

C2.4 safely conduct a chemical reaction in order to produce a common household or consumer product (e.g., taffy, shampoo, toothpaste, nylon, lip balm) [PR]

C2.5 classify various household products on the pH scale, using pH paper, indicator solutions, and/or a pH meter [PR, AI]

C2.6 investigate a variety of consumer products within a given category (e.g., shampoo, window cleaner, disinfectant), focusing on products claiming to be environmentally friendly, and analyse them with respect to selected factors (e.g., cost, effectiveness, impact on the environment) [PR, AI, C]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 describe the types of chemical reactions (e.g., synthesis, single displacement, double displacement, decomposition, combustion, polymerization, neutralization) and the signs of chemical change in each

C3.2 explain, in qualitative terms, why some chemical substances mix and others do not (e.g., ethanol and vinegar are both polar and therefore miscible)

C3.3 explain the function of the pH scale and how pH test results are interpreted

C3.4 identify organic and inorganic compounds commonly used in the home and workplace (*organic:* fats, oils, fuels, common solvents; *inorganic:* acids and bases, mineral solvents, ammonia, baking soda), and compare their properties

D. DISEASE AND ITS PREVENTION

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. evaluate the impact of public policy initiatives and technological advances intended to control the spread of disease, taking into consideration the failure of some people to follow public health regulations or recommendations;

D2. investigate the characteristics, growth, and spread of bacteria, and the effects of aseptic techniques and antibiotics;

D3. demonstrate an understanding of the causes, symptoms, and modes of transmission of various diseases, and of strategies to prevent the spread of disease.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 evaluate the effectiveness of a public policy measure or technological advance intended to control the spread of disease (e.g., mandatory immunization, screening for tuberculosis, quarantine) [AI, C]

Sample issue: The federal government established the Canadian Food Inspection Agency to ensure that the food eaten by Canadians is safe. Despite its regulations, food-borne illnesses such as salmonella, listeriosis, and mad cow disease continue to occur.

Sample questions: How effective are flu shots in reducing the incidence and severity of influenza, particularly among vulnerable populations like the elderly? What are some of the groups or organizations that track and inform the public of health risks? What tools and strategies do they use? How effective have they been in protecting human health?

D1.2 evaluate the impact, current and/or potential, of an individual's choice not to participate in a public health strategy intended to reduce the spread of disease (e.g., a hospital worker who does not follow recommendations regarding hand washing; a worker in a retirement home who does not get a flu shot) [AI, C]

Sample issue: Some parents are deciding not to immunize their children. Unvaccinated children can contract serious diseases such as polio and diphtheria and spread them to other unvaccinated children. The resurgence of such diseases would place a heavy burden on the health care system.

Sample questions: Why have signs showing proper hand-washing techniques been posted in many public restrooms? What can happen if someone in the food service industry ignores these signs? What can happen if a person infected with HIV refuses to use condoms?

D1.3 analyse, on the basis of research, the advantages and disadvantages of selected technologies used to try to control disease (e.g., the effectiveness of pharmaceuticals at combating disease; the side effects of a variety of drugs) [IP, PR, AI, C]

Sample issue: After World War II, DDT was widely used to kill insects that carried malaria. After researchers found that the pesticide caused abnormalities in some animals and cancer in humans, it was banned in many countries. However, in some countries with a high incidence of malaria, limited use of DDT continues.

Sample questions: What are the advantages and disadvantages of using insecticidal nets to try to control the spread of malaria? Why is the irradiation of food to eliminate food-borne bacteria controversial?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to the prevention of disease, including, but not limited to: *communicable, non-communicable, microorganism, pathogen, disease, epidemiology, vector, immunization record, quarantine, pandemic, vaccine, antiseptic, sterilization, disinfection,* and *pasteurization* [C]

D2.2 conduct an investigation, using safe practices and aseptic techniques, to compare the characteristics and growth of different types of non-pathogenic bacteria [PR, AI]

D2.3 investigate the effects of various drug therapies (e.g., different antibiotic discs) on the growth of bacteria [PR, AI]

D2.4 use a simulation (e.g., phenolphthalein and sodium hydroxide; a computer simulation) to demonstrate how diseases can spread through a community, and analyse the results [PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 describe modes of transmission of some communicable diseases, including those that are insect-borne (e.g., malaria, encephalitis), airborne (e.g., influenza, tuberculosis), waterborne (e.g., cholera, poliomyelitis), sexually transmitted (e.g., HIV/AIDS), and food-borne (e.g., mad cow disease, trichinosis, salmonella)

D3.2 identify the causes and symptoms of various diseases (e.g., AIDS, influenza, salmonella, West Nile virus), and describe measures intended to prevent their spread

D3.3 describe the reasons for immunization against specific diseases, the function of records of immunization in Ontario, and the importance of maintaining a personal immunization schedule

D3.4 describe the use of vaccines, antibiotics, antiseptics, and other medical measures, both conventional and alternative, intended to control disease

D3.5 explain the differences between bacteria and viruses in terms of their size, structure, and reproduction, and the methods used to control their spread

D3.6 explain the importance of the proper use, storage, and disposal of medications (e.g., the importance of taking the full course of antibiotics, following directions, keeping medications away from children, monitoring side effects, returning expired medication to a pharmacy for disposal)

E. ELECTRICITY AT HOME AND WORK

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. assess electrical hazards in the home and workplace, and the social and environmental impact of electrical technologies;

E2. investigate common electrical devices, including their energy transformations and consumption;

E3. demonstrate an understanding of electrical circuits, common electrical devices, and safety procedures related to electric systems.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 assess the social and environmental impact of electrical technologies, including the impact associated with the manufacture and disposal of electronic devices (e.g., the impact of electrical devices used in the health care field, such as pacemakers or respirators; the impact of energy generation needed to power electrical devices and appliances) [AI, C]

Sample issue: Electronics play an important part in our everyday lives. However, disposal of used electronic equipment is a huge problem. Globally, we generate 30 to 50 million tonnes of electronic waste each year. Much of this waste is shipped to developing countries, where it is incinerated or dumped in landfill sites, practices that release toxic chemicals into the air or soil.

Sample questions: How often do you replace an electronic device because something newer, faster, or more powerful has been developed? What do you do with the older devices? What impact have computers had on society?

E1.2 assess electrical hazards that can be found at home and in the workplace (e.g., electrical outlets close to areas where spills might occur; overloaded circuits), and propose practical courses of action to address the problems [AI, C]

Sample issue: Portable electric tools are convenient and efficient. However, if used improperly or if basic electrical safety precautions, such as proper grounding, are ignored, such tools can constitute a safety hazard.

Sample questions: What factors are important to consider when wiring a circuit in an area near water? What are the dangers of using electric hair dryers or razors near a sink full of water? What factors should be investigated when purchasing a home to ensure it meets the current electrical safety standards?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to electricity, including, but not limited to: *energy, power, kilowatt-hour, potential difference, current, conductor, short circuit, circuit breaker, fuse,* and *resistance* [C]

E2.2 draw energy flow diagrams and/or write energy transformation equations that illustrate the energy transformation occurring in household devices, including the production of waste energy (e.g., energy transformations in a digital music player: electrical energy → kinetic energy + sound energy + light + waste heat energy) [C]

E2.3 build a simple electrical device or circuit (e.g., a loudspeaker, an electric motor, a D-cell, a circuit containing a 40W lightbulb and a dimmer switch), following a clear set of instructions and diagrams, and using appropriate tools safely [PR]

E2.4 calculate the electrical energy consumption of two similar appliances (e.g., an old and a new refrigerator), using the power ratings that appear on the appliance, and compare the financial and environmental costs (e.g., carbon dioxide emissions) of running the two appliances [AI]

E2.5 analyse changes in household energy consumption over a given time period (e.g., throughout the course of a day; between a week in January and a week in May), and give reasons for the changes [AI, C]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe basic electric circuit components, including those that regulate the flow of electricity or are used as safety mechanisms (e.g., switches, bimetallic strips, resistors, ground fault interrupters [GFIs], surge protectors), and explain their layout in an electric circuit

E3.2 describe forms of energy (e.g., electrical, mechanical, sound, light, thermal) and the energy transformations that occur in common electrical devices, including production of waste energy (e.g., heat)

E3.3 identify situations in which direct current (DC) and alternating current (AC) are used (e.g., DC is used in a portable appliance such as a flashlight; AC is used in a household appliance such as a kettle)

E3.4 explain the difference in voltage requirements, and 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)

E3.5 describe safety procedures to be followed when using electric systems at home or at work (e.g., ensuring that tools and appliances are properly grounded; unplugging appliances by pulling the plug, not the cord), and explain how dangerous situations can occur (e.g., an overloaded circuit can overheat and cause a fire; digging through buried electrical cable can cause a severe shock)

F. NUTRITIONAL SCIENCE

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. assess the environmental implications of a variety of food choices, and evaluate and propose ways to improve the nutritional content of a menu;

F2. investigate nutrients and non-nutrient additives in a variety of foods;

F3. demonstrate an understanding of food components and their effects on the human body.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 assess the environmental implications of food choices available in a variety of situations (e.g., in the school cafeteria, a fast-food restaurant, a supermarket, a local farmers' market, an organic meat shop), and propose ways to minimize the environmental impact of their food choices [AI, C]

Sample issue: Supermarkets commonly sell imported produce, distributed through large warehouses, even when the same types of food are in season locally and are available from local farmers. Importing foods generates greater carbon emissions but may be seen as more efficient if local farmers lack a reliable distribution system.

Sample questions: What is the environmental impact of organic farming compared to traditional farming methods? What are the advantages and disadvantages of buying certified organic foods from a local farmer? What are the environmental costs of purchasing a pizza? Why is the environmental footprint associated with consuming a hamburger different from that associated with eating a veggie burger?

F1.2 evaluate the nutritional content of a menu (e.g., from the school cafeteria, a fast-food restaurant, a coffee shop, a retirement home, a hospital), and propose ways to improve it, using information from *Eating Well with Canada's Food Guide* or *Eating Well with Canada's Food Guide: First Nations, Inuit, and Métis* [AI, C]

Sample issue: The menus in fast-food restaurants tend to be high in fat, sodium, and sugar. However, there are many options such restaurants might consider, such as using whole grain buns, limiting the amount of salt added to burgers and fries, and providing additional menu choices that include fruits and vegetables.

Sample questions: Is a salad always a healthy choice at a restaurant? Why or why not? What is the nutritional difference between a serving of French fries and a baked potato served with the skin on? What is the nutritional difference between white bread and whole grain bread? What foods are high in protein? How many daily servings of fruits and vegetables are recommended by Canada's Food Guide? Why?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate vocabulary related to nutritional science, including, but not limited to: *nutrient, lipid, carbohydrate, protein, vitamin, mineral, qualitative test, serving size, food additive, trans fat, cholesterol, kilojoule, calorie, saturated, unsaturated, hydrogenated, essential amino acid,* and *preservative* [C]

F2.2 conduct an investigation to compare commercial food products and home-made foods (e.g., commercial and home-made cookies or cake; a shake from a fast-food restaurant and a home-made milk shake; commercial orange drink and freshly squeezed orange juice), with reference to qualitative and quantitative differences such as the number of ingredients, types of nutrients, non-nutrient additives, texture, and colour [PR, AI]

F2.3 conduct an investigation to test for the presence of various nutrients in foods (e.g., use iodine to test for starch; use Benedict's solution to test for simple sugar) [PR]

F2.4 plan and conduct an investigation into the effectiveness of food preservatives (e.g., use lemon juice to reduce oxidation of apple slices; compare mould growth on commercial and home-made bread) [IP, PR]

F2.5 modify a recipe or menu to meet a dietary restriction (e.g., reduce the cholesterol content by replacing whole eggs with egg whites; reduce the sodium content by cutting salt; replace milk with soy milk; replace meat with tofu or legumes), and explain the reasons for the changes (e.g., sodium can contribute to high blood pressure; dairy products can cause digestive problems for people who are lactose intolerant; non-animal sources of protein are necessary for vegans, who do not eat any animal products) [PR, C]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 identify sources of the principal food nutrients (e.g., carbohydrates, lipids, proteins, vitamins, minerals, fibre), with reference to Canada's Food Guide, and describe the function of these nutrients in the body

F3.2 identify the type of information commonly found on a food label, and describe how the information is organized (e.g., serving size, percentage of daily values, amount of each component)

F3.3 explain the meaning of a variety of descriptors found on food labels (e.g., "fat free", "low fat", "lite", "pure", "organic", "lean", "diet")

F3.4 describe the function of non-nutrient food additives (e.g., lecithin; monosodium glutamate [MSG]; artificial colour, flavour, and sweetener; preservatives), and explain their effects on human health

GLOSSARY

Note: This glossary covers terms from, and provides definitions within the context of, the Environmental Science and Science courses only.

absorption. The movement of a fluid or dissolved substance across a membrane.

adaptation. The occurrence of genetic changes in a population or species as the result of natural selection, enabling the population or species to adjust to new or altered environmental conditions.

air pollution. Chemicals, particulate matter, or biological materials in the atmosphere that harm living organisms or damage the environment.

alternative energy source. An energy source based on renewable resources (e.g., solar, wind, geothermal, tidal, hydroelectric sources).

antiseptic. A substance used to destroy or prevent the growth of infectious microorganisms on or in a body system.

aquatic environment. A water-based environment (e.g., pond, lake, river, ocean, underground water body).

aseptic technique. A technique used to ensure that a procedure is conducted under conditions free from pathogenic microorganisms.

bioamplification. Concentration of a persistent substance within an organism in the food chain.

biodegradable. A substance that can be broken down by microorganisms.

biodiversity. The variety of species (types) of organisms at all levels of classification in an ecosystem, and the variety of ecosystems, globally or within a specific geographic area.

biofuel. A solid, liquid, or gaseous fuel derived from carbon-based renewable resources (e.g., plants, organic waste).

biohazard / biological hazard. A biological agent or condition that presents a threat to living things.

bioremediation. A process that uses biological organisms, such as microorganisms, fungi, plants, or enzymes, to remove hazardous substances from a contaminated environment.

biosolid. The solid portion of sewage that contains primarily organic material produced by wastewater treatment processes and that can be used for different applications.

biosphere. The zone on Earth that can sustain life, including the lower part of the atmosphere, the hydrosphere, soil, and the upper parts of the lithosphere.

biotechnology. A technological application that uses microorganisms or biological substances to perform specific processes, including industrial, agricultural, and medical processes.

British thermal unit (BTU). A unit of measurement for heat. The amount of heat required to raise the temperature of one pound of liquid water by one degree Fahrenheit (from 60° to 61° F) at a constant pressure.

carbon footprint. A way of measuring the impact of human activities on the environment, a carbon footprint is the amount of greenhouse gases an activity produces, measured in units of carbon dioxide.

carbon neutral. Neither contributing to nor reducing net carbon emissions.

carrying capacity. The maximum population size of a given species that an ecosystem can support without reducing its ability to support the same species in the future.

chemical hazard. A chemical preparation in any form (solid, liquid, or gas) that presents a threat to living things.

chlorinated hydrocarbons. Compounds that contain chlorine, carbon, and hydrogen and are persistent in the environment.

cholesterol. A fat-like substance found in the blood and cells of humans and many other animals. Although it is essential to the cellular functioning of the body, too much cholesterol can contribute to the risk of stroke and heart disease.

chronic disease. A disease that is long lasting or recurrent (e.g., asthma, high blood pressure).

communicable disease. An infectious disease that can be transmitted from one individual to another through either direct contact or contact with inanimate objects or substances capable of carrying infectious organisms.

companion planting. The process of planting more than one type of plant in an area in such a way that they enhance the growth and quality of nearby plants (e.g., by repelling pests, providing ground cover, improving the soil).

compost. A mixture of decaying organic matter used to fertilize and condition the soil.

contaminants. Substances that, when accidentally or deliberately introduced into the environment, have the potential to harm people, animals, and/or plants.

conventional energy sources. Energy sources based on non-renewable resources (e.g., fossil fuels, nuclear energy).

crop rotation. A method of protecting the soil and replenishing its nutrients by planting a succession of different crops on the same land.

deforestation. The permanent clearance of a forest without replanting or natural regeneration.

designated substance regulations (DSR). Provincial laws regulating the exposure of workers to substances such as biological, chemical, and/or physical agents that are prohibited or controlled.

disease. Any condition that impairs normal functioning of tissues, organs, or body systems.

disinfectant. A chemical agent that destroys microorganisms but not bacterial spores.

disturbed environment. An environment that has been altered by human activity.

ecosystem. A complex, self-regulating system through which energy and materials are transferred, made up of a group of living organisms and their abiotic environment, which interact as a unit.

emulsification. The process of dispersing one liquid in a second immiscible liquid.

endangered species. An organism that is at risk of becoming extinct because it is either few in numbers or threatened by changing environmental factors or predation.

EnerGuide. A rating system for home appliances based on the cost in energy of operating the appliance.

environmental contaminants. Toxic substances that, when accidentally or intentionally introduced to the environment, can harm people, animals, and/or plants.

environmental factors. A range of chemical or biological substances or climate-related phenomena in the surrounding environment that can affect the health of living things.

environmental impact assessments. A formal study of the environmental effects that are likely to occur as a result of major developments such as new legislation or industrial or urban expansion.

environmental scan. A process that provides base line information about a program, environment, or region that is going to be studied.

environmental stress. Pressures on the environment from external and internal sources such as pollution, toxins, and climate.

enzymes. Proteins produced by living cells that speed up reactions.

epidemiology. The study of the mass aspects of disease.

essential amino acid. Any of the 8 of 20 naturally occurring amino acids that are indispensable for optimum animal growth but cannot be formed by the body and therefore must be supplied in the diet.

fact. Something that is true, something that actually exists, or something having objective reality that can be verified according to an established standard of evaluation.

feedback loop. A system with inputs and outputs, in which the information from the input is sent to the output and back again to the input.

food additives. Substances added to foods during processing to improve colour, texture, flavour, and/or shelf life.

gene therapy. The process of using normal genes to supplement or replace defective genes or to bolster normal functions.

genetic engineering. The intentional production of new genes and alteration of genomes by the substitution or introduction of new genetic material.

genetically modified organism (GMO). An organism in which genetic material has been altered using genetic engineering techniques.

genome. The genetic makeup of a species.

genomics. The study of an organism's entire genome.

greenhouse gas. An atmospheric gas that allows solar radiation to pass through the atmosphere but absorbs the radiation Earth emits back to space, thereby trapping heat and making the planet's surface warmer. These gases include carbon dioxide, water vapour, methane, and the fluorocarbons.

Hazardous Household Product Symbols (HHPS). Symbols that are located on some household chemical products to identify the dangers associated with the use of or exposure to the product.

hazardous material. A toxic, corrosive, flammable, explosive, or radioactive chemical or other material that can endanger human health or well-being if handled improperly.

heavy metals. A metal whose specific gravity is approximately 5.0 or higher. Heavy metals are persistent in the environment and can accumulate in plants and animals, causing health problems.

hybridization. The act or process of producing hybrids.

hydrogenated. Hydrogenation is a catalytic reaction of hydrogen with compounds that are usually in an unsaturated form. In the food industry, hydrogenation is used to process liquid oils into solid or semi-solid fats.

immunization record. A provincial document that is required by law for attendance in Ontario schools and that indicates the immunizations required for Ontario children.

infectious disease. A disease caused by pathogens that invade, and subsequently multiply in, the body.

infectious materials. Materials that contain pathogens such as bacteria, viruses, fungi, and parasites that can harm people or animals.

inference. The act or process of deriving a conclusion based solely on what one knows or observes.

ingestion. The process of taking food or other substances into the body through the mouth.

inhalation. The process of breathing in. It is one of the modes by which foreign substances can enter the body.

inorganic compound. A substance that does not contain carbon as its principal element; matter that is neither plant nor animal.

inorganic waste. Waste that is composed of chemical compounds that do not contain carbon as their principal element; waste whose source is neither plant nor animal.

Integrated Pest Management. An ecological approach that uses an array of complementary methods to control pests. These methods may include mechanical and physical devices; genetic, biological, and chemical management; and cultural practices.

invasive species. Non-indigenous species that have adverse environmental, ecological, or economic effects on the habitats they invade.

joule (j). A unit of energy or work, a joule represents the work done by a force of one newton applied through a displacement of one metre in the direction of a force.

kilojoule (kJ). A unit of energy or work equal to 1000 joules.

kilowatt. A unit of power equal to 1000 watts.

kilowatt-hour (kWh). A unit of energy or work equal to that expended by one kilowatt in one hour.

life-cycle assessments. A process for evaluating the inputs and outputs of materials and energy at each stage in the life cycle of a product, from raw materials to final disposal.

macromolecule. A large molecule (e.g., a carbohydrate).

Material Safety Data Sheet (MSDS). A workplace-related document that contains information on the safe use, storage, and handling of chemical products as well as the potential hazards and emergency measures associated with these products.

Möbius loop (waste management). The symbol used to indicate that an object can be recycled or is made of recycled materials.

mutation. An abrupt change, either qualitative or quantitative, in the genotype of an organism, not resulting from recombination.

native species. Those species indigenous to a particular area or region that have evolved over thousands of years, adapting to their surroundings, and have become an important part of the local ecosystem.

natural environment. An environment that has not been altered by human activity.

naturalization. A process whereby a species becomes permanently established after being introduced.

neutralization. The process of making a solution neutral (pH = 7) by adding a base to an acid solution, or adding an acid to an alkaline (basic) solution.

non-communicable disease. A disease that is not infectious and is caused by something other than a pathogen.

non-renewable energy sources. Energy sources that cannot be replenished in a short period of time (e.g., fossil fuels, nuclear energy).

nutrient. A food or chemical that an organism needs to live and grow; a substance used in an organism's metabolism that must be taken in from its environment.

nutritional supplement. A preparation intended to supply nutrients, such as vitamins, minerals, fatty acids, or amino acids, that are missing from, or not in sufficient quantities in, a person's diet.

occupational exposure limits (OEL). Limits for concentrations of hazardous compounds in workplace air.

organic compounds. Any member of a large class of chemical compounds whose molecules contain carbon.

organic products. Foods and other agricultural products that come from a farm system that uses ecologically sustainable practices based on the principles of interdependency, diversity, and recycling. Organic farms use natural weed and pest control as opposed to chemical pesticides, recycle animal and plant residue as opposed to using chemical fertilizers, and generally do not include genetically modified organisms.

organic waste. Biodegradable waste composed of carbon compounds derived from plants or animals.

pandemic. An epidemic occurring over a widespread geographic area.

paradigm. The set of theories and practices that define a discipline during a particular period of time.

parasite. An organism that lives in a close relationship with or on another organism (its host) and takes nourishment from the organism, causing it harm.

pasteurization. The application of heat to matter for a specific time to destroy harmful microorganisms or other undesirable species.

pathogen. A disease-producing agent, usually a living organism.

pathogenesis. The origin and course of development of a disease.

personal protective equipment (PPE). Equipment worn by a worker to minimize exposure to specific occupational hazards.

pesticide. A chemical substance or mixture of substances intended to destroy or repel a pest or prevent a pest from establishing itself in an area.

polychlorinated biphenyls (PCBs). An organic compound that is a member of the group of chlorinated isomers of biphenyl. The compound, which was commonly used in coolants and lubricants, is highly toxic.

polymerization. A chemical reaction that combines many small repeating groups (monomers) into a large molecule (polymer).

population. The number of individuals of a specific species in a specific area at a specific time.

preservative. A chemical added to foodstuffs to prevent oxidization, fermentation, or other deterioration, usually by inhibiting the growth of bacteria.

quarantine. Limitations to freedom of movement of susceptible individuals who have been exposed to communicable diseases, for a period of time equal to the incubation period of the disease.

R-value. An index of the ability of a substance or material to retard the flow of heat; higher numerical values correspond to higher insulating ability.

recyclable. A material or product that can be diverted from waste and processed into a new product.

renewable energy sources. Energy sources that can be replenished in a short period of time (e.g., solar, wind, geothermal sources).

respiration. The act or process by which an organism exchanges gases with its environment.

sample size. The number of items in a given area or sample.

selective breeding. A process of breeding plants or animals for desirable traits.

silviculture. The theory and practice of controlling the establishment, composition, and growth of forests for a particular purpose.

smog. A mixture of air pollutants, with ground-level ozone as the main component.

soot. The black impure carbon particles resulting from the incomplete combustion of a hydrocarbon.

sterilization. An act or process of destroying all forms of microbial life on and in an object.

succession. A gradual process brought about by change in the number of individuals of each species in a community and by the establishment of new species populations that may gradually replace the original inhabitants.

sustainability. The capacity to maintain a certain process or state indefinitely.

tailings. Waste consisting of ground rock and effluents that result from processing in the mining industry.

terrestrial environment. An environment based on land (e.g., forests, grasslands).

threatened species. A category of species that is under threat of extinction, or that is endangered, vulnerable, or becoming rare in a given environment.

titration. A method of analysing the composition of a solution by adding known amounts of a standardized solution until a given reaction (colour or conductivity change, precipitate formation) is produced.

toxic waste. Waste containing a poisonous substance that has a harmful effect on the body.

vaccination. Inoculation with viral or bacterial organisms or antigens to produce immunity in the recipient.

vaccine. A product that protects an organism from disease by producing immunity to a pathogen.

watt. A unit of power equal to 1 joule per second.

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