

Physics 3204

Curriculum Guide 2019



Education and Early Childhood Development

***Department of Education and Early
Childhood Development
Mission Statement***

***The Department of Education and Early
Childhood Development will improve
provincial early childhood learning
and the K-12 education system to
further opportunities for the people of
Newfoundland and Labrador.***

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Section One: Newfoundland and Labrador Curriculum

Introduction

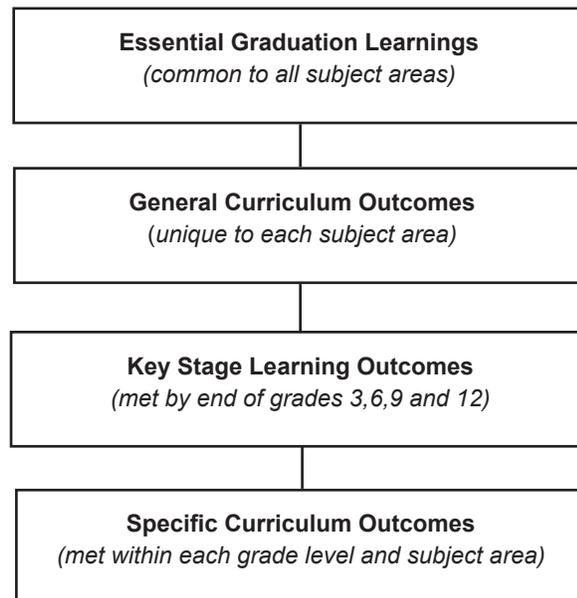
There are multiple factors that impact education: technological developments, increased emphasis on accountability, and globalization. These factors point to the need to consider carefully the education students receive.

The Newfoundland and Labrador Department of Education and Early Childhood Development believes that curriculum design with the following characteristics will help teachers address the needs of students served by the provincially prescribed curriculum:

- Curriculum guides must clearly articulate what students are expected to know and be able to do by the time they graduate from high school.
- There must be purposeful assessment of students' performance in relation to the curriculum outcomes.

Outcomes Based Education

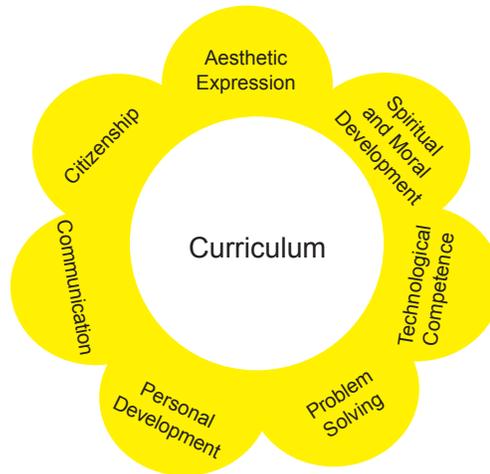
The K-12 curriculum in Newfoundland and Labrador is organized by outcomes and is based on *The Atlantic Canada Framework for Essential Graduation Learning in Schools* (1997). This framework consists of Essential Graduation Learnings (EGLs), General Curriculum Outcomes (GCOs), Key Stage Curriculum Outcomes (KSCOs) and Specific Curriculum Outcomes (SCOs).



Essential Graduation Learnings

EGLs provide vision for the development of a coherent and relevant curriculum. They are statements that offer students clear goals and a powerful rationale for education. The EGLs are delineated by general, key stage, and specific curriculum outcomes.

EGLs describe the knowledge, skills, and attitudes expected of all students who graduate from high school. Achievement of the EGLs will prepare students to continue to learn throughout their lives. EGLs describe expectations, not in terms of individual subject areas, but in terms of knowledge, skills, and attitudes developed throughout the K-12 curriculum. They confirm that students need to make connections and develop abilities across subject areas if they are to be ready to meet the shifting and ongoing demands of life, work, and study.



Aesthetic Expression – Graduates will be able to respond with critical awareness to various forms of the arts and be able to express themselves through the arts.

Citizenship – Graduates will be able to assess social, cultural, economic, and environmental interdependence in a local and global context.

Communication – Graduates will be able to use the listening, viewing, speaking, reading and writing modes of language(s), and mathematical and scientific concepts and symbols, to think, learn and communicate effectively.

Problem Solving – Graduates will be able to use the strategies and processes needed to solve a wide variety of problems, including those requiring language, and mathematical and scientific concepts.

Personal Development – Graduates will be able to continue to learn and to pursue an active, healthy lifestyle.

Spiritual and Moral Development – Graduates will demonstrate understanding and appreciation for the place of belief systems in shaping the development of moral values and ethical conduct.

Technological Competence – Graduates will be able to use a variety of technologies, demonstrate an understanding of technological applications, and apply appropriate technologies for solving problems.

Curriculum Outcomes

Curriculum outcomes are statements that articulate what students are expected to know and be able to do in each program area in terms of knowledge, skills, and attitudes.

Curriculum outcomes may be subdivided into General Curriculum Outcomes, Key Stage Curriculum Outcomes, and Specific Curriculum Outcomes.

General Curriculum Outcomes (GCOs)

Each program has a set of GCOs which describe what knowledge, skills, and attitudes students are expected to demonstrate as a result of their cumulative learning experiences within a subject area. GCOs serve as conceptual organizers or frameworks which guide study within a program area. Often, GCOs are further delineated into KSCOs.

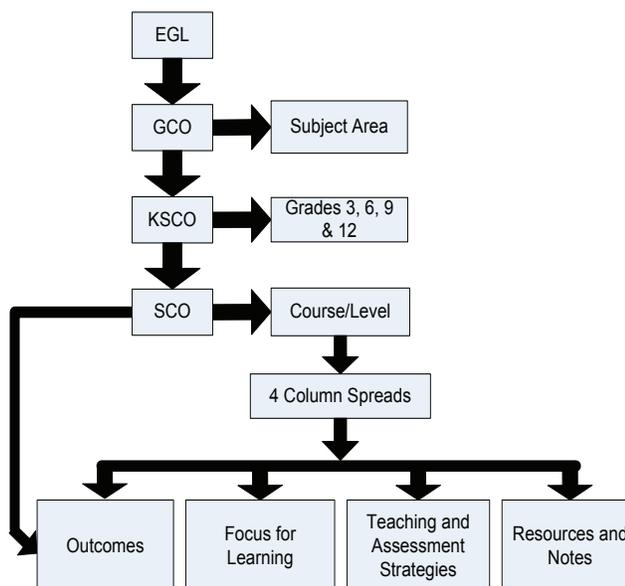
Key Stage Curriculum Outcomes (KSCOs)

Key Stage Curriculum Outcomes (KSCOs) summarize what is expected of students at each of the four key stages of grades three, six, nine, and twelve.

Specific Curriculum Outcomes (SCOs)

SCOs set out what students are expected to know and be able to do as a result of their learning experiences in a course, at a specific grade level. In some program areas, SCOs are further articulated into delineations. *It is expected that all SCOs will be addressed during the course of study covered by the curriculum guide.*

EGLs to Curriculum Guides



Context for Teaching and Learning

Teachers are responsible to help students achieve outcomes. This responsibility is a constant in a changing world. As programs change over time so does educational context. Several factors make up the educational context in Newfoundland and Labrador today: inclusive education, support for gradual release of responsibility teaching model, focus on literacy and learning skills in all programs, and support for education for sustainable development.

Inclusive Education

Valuing Equity and Diversity

Effective inclusive schools have the following characteristics: supportive environment, positive relationships, feelings of competence, and opportunities to participate. (The Centre for Inclusive Education, 2009)

All students need to see their lives and experiences reflected in their school community. It is important that the curriculum reflect the experiences and values of all genders and that learning resources include and reflect the interests, achievements, and perspectives of all students. An inclusive classroom values the varied experiences and abilities as well as social and ethno-cultural backgrounds of all students while creating opportunities for community building. Inclusive policies and practices promote mutual respect, positive interdependencies, and diverse perspectives. Learning resources should include a range of materials that allow students to consider many viewpoints and to celebrate the diverse aspects of the school community.



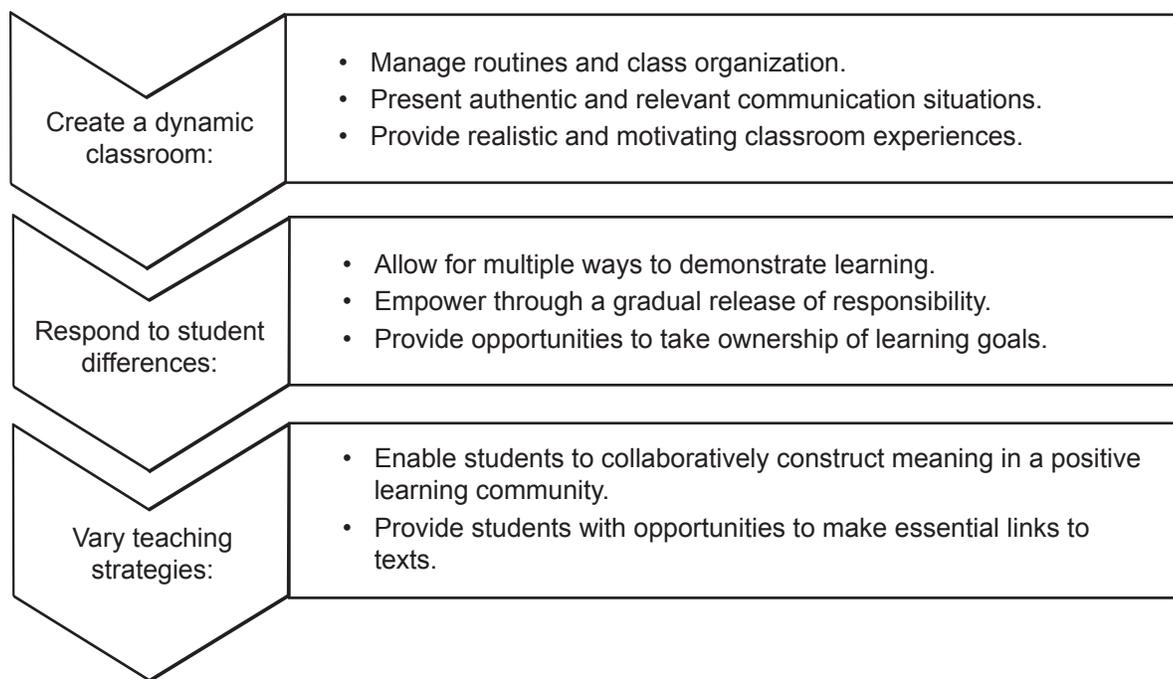
Differentiated Instruction

Differentiated instruction is a teaching philosophy based on the premise that teachers should adapt instruction to student differences. Rather than marching students through the curriculum lockstep, teachers should modify their instruction to meet students' varying readiness levels, learning preferences, and interests. Therefore, the teacher proactively plans a variety of ways to 'get it' and express learning. (Carol Ann Tomlinson, 2008)

Curriculum is designed and implemented to provide learning opportunities for all students according to abilities, needs, and interests. Teachers must be aware of and responsive to the diverse range of learners in their classes. Differentiated instruction is a useful tool in addressing this diversity.

Differentiated instruction responds to different readiness levels, abilities, and learning profiles of students. It involves actively planning so that the process by which content is delivered, the way the resource is used, and the products students create are in response to the teacher's knowledge of whom he or she is interacting with. Learning environments should be flexible to accommodate various learning preferences of the students. Teachers continually make decisions about selecting teaching strategies and structuring learning activities that provide all students with a safe and supportive place to learn and succeed.

Planning for Differentiation



Differentiating the Content

Differentiating content requires teachers to pre-assess students to identify those who require prerequisite instruction, as well as those who have already mastered the concept and may therefore apply strategies learned to new situations. Another way to differentiate content is to permit students to adjust the pace at which they progress through the material. Some students may require additional time while others will move through at an increased pace and thus create opportunities for enrichment or more in-depth consideration of a topic of particular interest.

Teachers should consider the following examples of differentiating content:

- Meet with small groups to reteach an idea or skill or to extend the thinking or skills.
- Present ideas through auditory, visual, and tactile means.
- Use reading materials such as novels, websites, and other reference materials at varying reading levels.

Differentiating the Process

Differentiating the process involves varying learning activities or strategies to provide appropriate methods for students to explore and make sense of concepts. A teacher might assign all students the same product (e.g., presenting to peers) but the process students use to create the presentation may differ. Some students could work in groups while others meet with the teacher individually. The same assessment criteria can be used for all students.

Teachers should consider flexible grouping of students such as whole class, small group, or individual instruction. Students can be grouped according to their learning styles, readiness levels, interest areas, and/or the requirements of the content or activity presented. Groups should be formed for specific purposes and be flexible in composition and short-term in duration.

Teachers should consider the following examples of differentiating the process:

- Offer hands-on activities for students.
- Provide activities and resources that encourage students to further explore a topic of particular interest.
- Use activities in which all learners work with the same learning outcomes but proceed with different levels of support, challenge, or complexity.

Differentiating the Product

Differentiating the product involves varying the complexity and type of product that students create to demonstrate learning outcomes. Teachers provide a variety of opportunities for students to demonstrate and show evidence of what they have learned.

Teachers should give students options to demonstrate their learning (e.g., create an online presentation, write a letter, or develop a mural). This will lead to an increase in student engagement.

Differentiating the Learning Environment

The learning environment includes the physical and the affective tone or atmosphere in which teaching and learning take place, and can include the noise level in the room, whether student activities are static or mobile, or how the room is furnished and arranged. Classrooms may include tables of different shapes and sizes, space for quiet individual work, and areas for collaboration.

Teachers can divide the classroom into sections, create learning centres, or have students work both independently and in groups. The structure should allow students to move from whole group, to small group, pairs, and individual learning experiences and support a variety of ways to engage in learning. Teachers should be sensitive and alert to ways in which the classroom environment supports their ability to interact with students.

Teachers should consider the following examples of differentiating the learning environment:

- Develop routines that allow students to seek help when teachers are with other students and cannot provide immediate attention.
- Ensure there are places in the room for students to work quietly and without distraction, as well as places that invite student collaboration.
- Establish clear guidelines for independent work that match individual needs.
- Provide materials that reflect diversity of student background, interests, and abilities.

The physical learning environment must be structured in such a way that all students can gain access to information and develop confidence and competence.

Meeting the Needs of Students with Exceptionalities

All students have individual learning needs. Some students, however, have exceptionalities (defined by the Department of Education and Early Childhood Development) which impact their learning. The majority of students with exceptionalities access the prescribed curriculum. For details of these exceptionalities see www.gov.nl.ca/edu/k12/studentssupportservices/exceptionalities.html

Supports for these students may include

1. Accommodations
2. Modified Prescribed Courses
3. Alternate Courses
4. Alternate Programs
5. Alternate Curriculum

For further information, see Service Delivery Model for Students with Exceptionalities at www.cdli.ca/sdm/

Classroom teachers should collaborate with instructional resource teachers to select and develop strategies which target specific learning needs.

*Meeting the Needs
of Students who are
Highly Able
(includes gifted and
talented)*

Some students begin a course or topic with a vast amount of prior experience and knowledge. They may know a large portion of the material before it is presented to the class or be capable of processing it at a rate much faster than their classmates. All students are expected to move forward from their starting point. Many elements of differentiated instruction are useful in addressing the needs of students who are highly able.

Teachers may

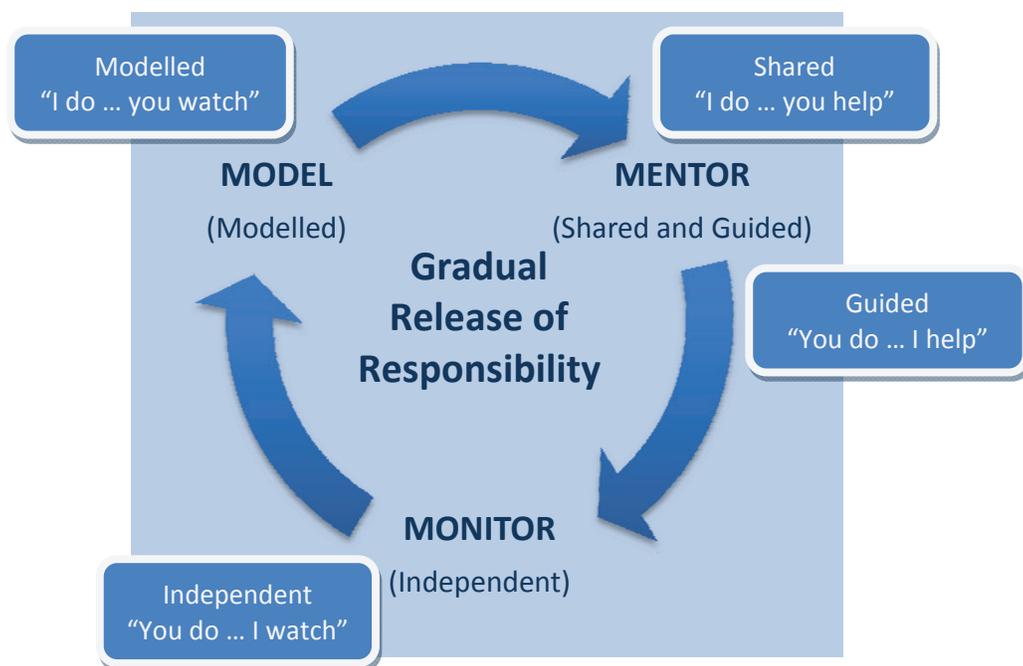
- assign independent study to increase depth of exploration in an area of particular interest;
- compact curriculum to allow for an increased rate of content coverage commensurate with a student's ability or degree of prior knowledge;
- group students with similar abilities to provide the opportunity for students to work with their intellectual peers and elevate discussion and thinking, or delve deeper into a particular topic; and
- tier instruction to pursue a topic to a greater depth or to make connections between various spheres of knowledge.

Highly able students require the opportunity for authentic investigation to become familiar with the tools and practices of the field of study. Authentic audiences and tasks are vital for these learners. Some highly able learners may be identified as gifted and talented in a particular domain. These students may also require supports through the Service Delivery Model for Students with Exceptionalities.

Gradual Release of Responsibility

Teachers must determine when students can work independently and when they require assistance. In an effective learning environment, teachers choose their instructional activities to model and scaffold composition, comprehension, and metacognition that is just beyond the students' independence level. In the gradual release of responsibility approach, students move from a high level of teacher support to independent work. If necessary, the teacher increases the level of support when students need assistance. The goal is to empower students with their own learning strategies, and to know how, when, and why to apply them to support their individual growth. Guided practice supports student independence. As a student demonstrates success, the teacher should gradually decrease his or her support.

Gradual Release of Responsibility Model



Literacy

“Literacy is the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society”. To be successful, students require a set of interrelated skills, strategies and knowledge in multiple literacies that facilitate their ability to participate fully in a variety of roles and contexts in their lives, in order to explore and interpret the world and communicate meaning. (The Plurality of Literacy and its Implications for Policies and Programmes, 2004, p.13)

Literacy is

- a process of receiving information and making meaning from it; and
- the ability to identify, understand, interpret, communicate, compute, and create text, images, and sounds.

Literacy development is a lifelong learning enterprise beginning at birth that involves many complex concepts and understandings. It is not limited to the ability to read and write; no longer are we exposed only to printed text. It includes the capacity to learn to communicate, read, write, think, explore, and solve problems. Individuals use literacy skills in paper, digital, and live interactions to engage in a variety of activities:

- Analyze critically and solve problems.
- Comprehend and communicate meaning.
- Create a variety of texts.
- Make connections both personally and inter-textually.
- Participate in the socio-cultural world of the community.
- Read and view for enjoyment.
- Respond personally.

These expectations are identified in curriculum documents for specific subject areas as well as in supporting documents, such as *Cross-Curricular Reading Tools (CAMET)*.

With modelling, support, and practice, students' thinking and understandings are deepened as they work with engaging content and participate in focused conversations.

Reading in the Content Areas

The focus for reading in the content areas is on teaching strategies for understanding content. Teaching strategies for reading comprehension benefits all students as they develop transferable skills that apply across curriculum areas.

When interacting with different texts, students must read words, view and interpret text features, and navigate through information presented in a variety of ways including, but not limited to

Advertisements	Movies	Poems
Blogs	Music videos	Songs
Books	Online databases	Speeches
Documentaries	Plays	Video games
Magazine articles	Podcasts	Websites

Students should be able to interact with and comprehend different texts at different levels.

There are three levels of text comprehension:

- Independent level – Students are able to read, view, and understand texts without assistance.
- Instructional level – Students are able to read, view, and understand most texts but need assistance to fully comprehend some texts.
- Frustration level – Students are not able to read or view with understanding (i.e., texts may be beyond their current reading level).

Teachers will encounter students working at all reading levels in their classrooms and will need to differentiate instruction to meet their needs. For example, print texts may be presented in audio form, physical movement may be associated with synthesizing new information with prior knowledge, or graphic organizers may be created to present large amounts of print text in a visual manner.

When interacting with information that is unfamiliar to students, it is important for teachers to monitor how effectively students are using strategies to read and view texts:

- Analyze and think critically about information.
- Determine importance to prioritize information.
- Engage in questioning before, during, and after an activity related to a task, text, or problem.
- Make inferences about what is meant but not said.
- Make predictions.
- Synthesize information to create new meaning.
- Visualize ideas and concepts.

Learning Skills for Generation Next

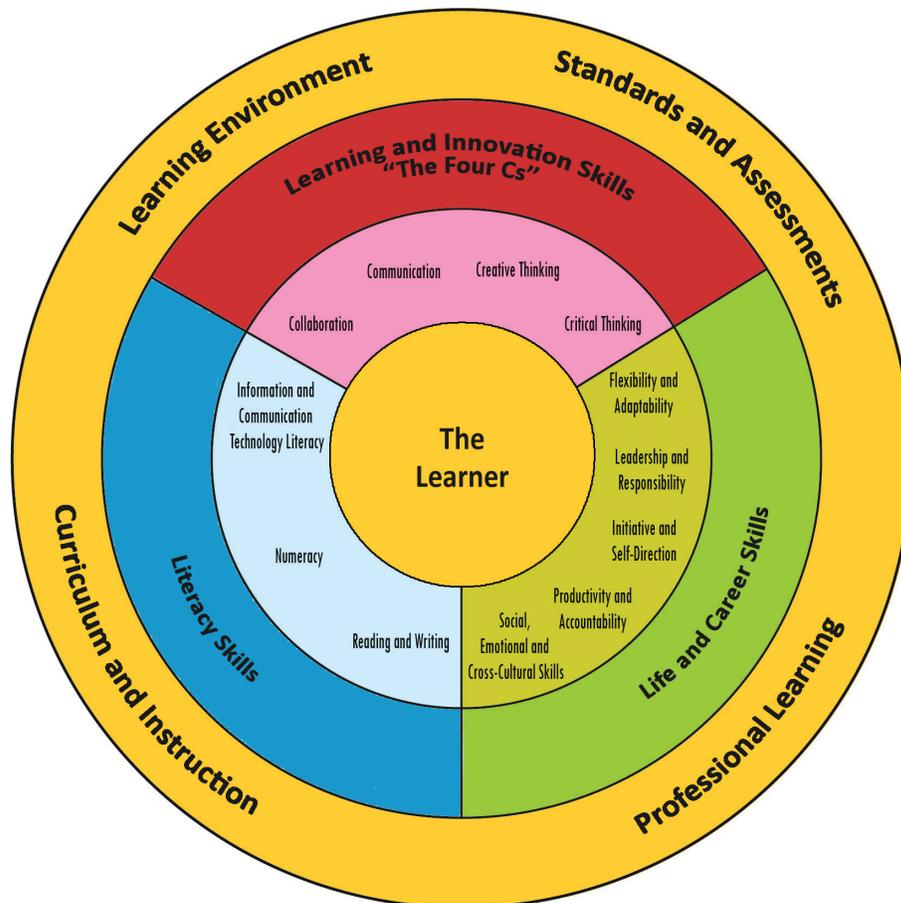
Generation Next is the group of students who have not known a world without personal computers, cell phones, and the Internet. They were born into this technology. They are digital natives.

Students need content and skills to be successful. Education helps students learn content and develop skills needed to be successful in school and in all learning contexts and situations. Effective learning environments and curricula challenge learners to develop and apply key skills within the content areas and across interdisciplinary themes.

Learning Skills for Generation Next encompasses three broad areas:

- Learning and Innovation Skills enhance a person's ability to learn, create new ideas, problem solve, and collaborate.
- Life and Career Skills address leadership, and interpersonal and affective domains.
- Literacy Skills develop reading, writing, and numeracy, and enhance the use of information and communication technology.

The diagram below illustrates the relationship between these areas. A 21st century curriculum employs methods that integrate innovative and research-driven teaching strategies, modern learning technologies, and relevant resources and contexts.



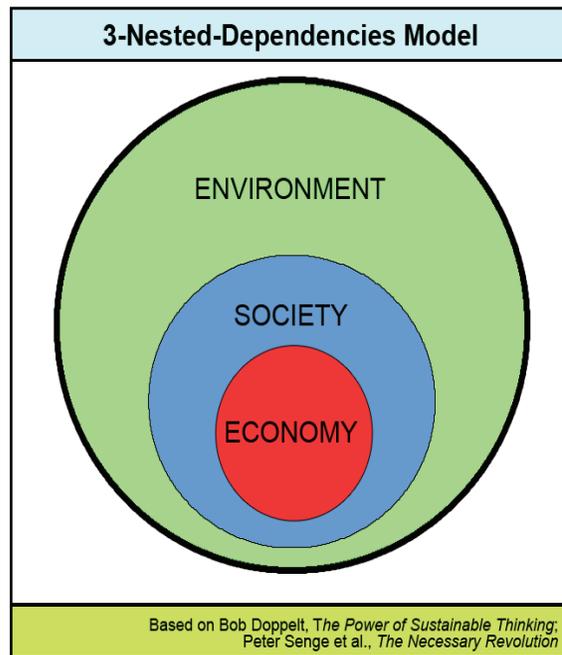
Support for students to develop these abilities and skills is important across curriculum areas and should be integrated into teaching, learning, and assessment strategies. Opportunities for integration of these skills and abilities should be planned with engaging and experiential activities that support the gradual release of responsibility model. For example, lessons in a variety of content areas can be infused with learning skills for Generation Next by using open-ended questioning, role plays, inquiry approaches, self-directed learning, student role rotation, and Internet-based technologies.

All programs have a shared responsibility in developing students' capabilities within all three skill areas.

Education for Sustainable Development

Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. (Our Common Future, 43)

Sustainable development is comprised of three integrally connected areas: economy, society, and environment.



As conceived by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) the overall goal of Education for Sustainable Development (ESD) is to integrate the knowledge, skills, values, and perspectives of sustainable development into all aspects of education and learning. Changes in human behaviour should create a more sustainable future that supports environmental integrity and economic viability, resulting in a just society for all generations.

ESD involves teaching *for* rather than teaching *about* sustainable development. In this way students develop the skills, attitudes, and perspectives to meet their present needs without compromising the ability of future generations to meet their needs.

Within ESD, the knowledge component spans an understanding of the interconnectedness of our political, economic, environmental, and social worlds, to the role of science and technology in the development of societies and their impact on the environment. The skills necessary include being able to assess bias, analyze consequences of choices, ask questions, and solve problems. ESD values and perspectives include an appreciation for the interdependence of all life forms, the importance of individual responsibility and action, an understanding of global issues as well as local issues in a global context. Students need to be aware that every issue has a history, and that many global issues are linked.

Assessment and Evaluation

Assessment

Assessment is the process of gathering information on student learning.

How learning is assessed and evaluated and how results are communicated send clear messages to students and others about what is valued.

Assessment instruments are used to gather information for evaluation. Information gathered through assessment helps teachers determine students' strengths and needs, and guides future instruction.

Teachers are encouraged to be flexible in assessing student learning and to seek diverse ways students might demonstrate what they know and are able to do.

Evaluation involves the weighing of the assessment information against a standard in order to make a judgement about student achievement.

Assessment can be used for different purposes:

1. Assessment *for* learning guides and informs instruction.
2. Assessment *as* learning focuses on what students are doing well, what they are struggling with, where the areas of challenge are, and what to do next.
3. Assessment *of* learning makes judgements about student performance in relation to curriculum outcomes.

1. *Assessment for Learning*

Assessment *for* learning involves frequent, interactive assessments designed to make student learning visible. This enables teachers to identify learning needs and adjust teaching accordingly.

Assessment *for* learning is not about a score or mark; it is an ongoing process of teaching and learning:

- Pre-assessments provide teachers with information about what students already know and can do.
- Self-assessments allow students to set goals for their own learning.
- Assessment *for* learning provides descriptive and specific feedback to students and parents regarding the next stage of learning.
- Data collected during the learning process from a range of tools enables teachers to learn as much as possible about what a student knows and is able to do.

2. *Assessment as Learning*

Assessment as learning involves students' reflecting on their learning and monitoring their own progress. It focuses on the role of the student in developing metacognition and enhances engagement in their own learning. Students can

- analyze their learning in relation to learning outcomes,
- assess themselves and understand how to improve performance,
- consider how they can continue to improve their learning, and
- use information gathered to make adaptations to their learning processes and to develop new understandings.

3. *Assessment of Learning*

Assessment of learning involves strategies designed to confirm what students know in terms of curriculum outcomes. It also assists teachers in determining student proficiency and future learning needs. *Assessment of learning* occurs at the end of a learning experience and contributes directly to reported results. Traditionally, teachers relied on this type of assessment to make judgements about student performance by measuring learning after the fact and then reporting it to others. Used in conjunction with the other assessment processes previously outlined, *assessment of learning* is strengthened. Teachers can

- confirm what students know and can do;
- report evidence to parents/guardians, and other stakeholders, of student achievement in relation to learning outcomes; and
- report on student learning accurately and fairly using evidence obtained from a variety of contexts and sources.

Involving Students in the Assessment Process

Students should know what they are expected to learn as outlined in the specific curriculum outcomes of a course as well as the criteria that will be used to determine the quality of their achievement. This information allows students to make informed choices about the most effective ways to demonstrate what they know and are able to do.

It is important that students participate actively in assessment by co-creating criteria and standards which can be used to make judgements about their own learning. Students may benefit from examining various scoring criteria, rubrics, and student exemplars.

Students are more likely to perceive learning as its own reward when they have opportunities to assess their own progress. Rather than asking teachers, "What do you want?", students should be asking themselves questions:

- What have I learned?
- What can I do now that I couldn't do before?
- What do I need to learn next?

Assessment must provide opportunities for students to reflect on their own progress, evaluate their learning, and set goals for future learning.

Assessment Tools

In planning assessment, teachers should use a broad range of tools to give students multiple opportunities to demonstrate their knowledge, skills, and attitudes. The different levels of achievement or performance may be expressed as written or oral comments, ratings, categorizations, letters, numbers, or as some combination of these forms.

The grade level and the activity being assessed will inform the types of assessment tools teachers will choose:

Anecdotal Records	Photographic Documentation
Audio/Video Clips	Podcasts
Case Studies	Portfolios
Checklists	Presentations
Conferences	Projects
Debates	Questions
Demonstrations	Quizzes
Exemplars	Role Plays
Graphic Organizers	Rubrics
Journals	Self-assessments
Literacy Profiles	Tests
Observations	Wikis

Assessment Guidelines

Assessments should measure what they intend to measure. It is important that students know the purpose, type, and potential marking scheme of an assessment. The following guidelines should be considered:

- Collect evidence of student learning through a variety of methods; do not rely solely on tests and paper and pencil activities.
- Develop a rationale for using a particular assessment of learning at a specific point in time.
- Provide descriptive and individualized feedback to students.
- Provide students with the opportunity to demonstrate the extent and depth of their learning.
- Set clear targets for student success using learning outcomes and assessment criteria.
- Share assessment criteria with students so that they know the expectations.

Evaluation

Evaluation is the process of analyzing, reflecting upon, and summarizing assessment information, and making judgements or decisions based on the information gathered. Evaluation is conducted within the context of the outcomes, which should be clearly understood by learners before teaching and evaluation take place. Students must understand the basis on which they will be evaluated and what teachers expect of them.

During evaluation, the teacher interprets the assessment information, makes judgements about student progress, and makes decisions about student learning programs.

Section Two: Curriculum Design

Rationale

The vision of science education in Newfoundland and Labrador is to develop scientific literacy.

Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem solving, and decision making abilities; to become lifelong learners; and to maintain a sense of wonder about the world around them.

To develop scientific literacy, students require diverse learning experiences which provide opportunities to explore, analyze, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, careers, and futures.

Science education which strives for scientific literacy must engage students in science inquiry, problem solving, and decision making.

Science Inquiry

Science inquiry involves posing questions and developing explanations for phenomena. While there is general agreement that there is no such thing as “the” scientific method, students require certain skills to participate in the activities of science. Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, collecting data, analyzing data, and interpreting data are fundamental to engaging in science. These skills are often represented as a cycle which involves the posing of questions, the generation of possible explanations, and the collection of evidence to determine which of these explanations is most useful in accounting for the phenomenon under investigation. Teachers should engage students in science inquiry activities to develop these skills.

Problem Solving

Problem solving involves seeking solutions to human problems. It may be represented as a cycle consisting of the proposing, creating, and testing of prototypes, products, and techniques in and attempt to reach an optimum solution to a given problem. The skills involved in this cycle facilitate a process which has different aims and procedures from science inquiry. Students should be given opportunities to propose, perform, and evaluate solutions to problem solving or technological tasks.

Decision Making

Decision making involves determining what we should do in a particular context or in response to a given situation. Increasingly, the types of problems that we deal with, both individually and collectively, require an understanding of the processes and products of science and technology. The process of decision making involves identification of the problem or situation, generation of possible solutions or courses of action, evaluation of the alternatives, and a thoughtful decision based on the information available. Students should be actively involved in decision making situations. While important in their own right, decision making situations also provide a relevant context for engaging in science inquiry and/or problem solving.

Curriculum Outcomes Framework

General Curriculum Outcomes

The foundation of the curriculum outcomes framework are the general curriculum outcomes (GCOs). Four general curriculum outcomes have been identified to delineate the four critical aspects of students' scientific literacy: science, technology, society, and the environment (STSE), skills, knowledge, and attitudes. These four GCOs are common to all science courses.

GCO 1: Science, Technology, Society, and the Environment

Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

GCO 2: Skills

Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

GCO 3: Knowledge

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

GCO 4: Attitudes

Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Key Stage Curriculum Outcomes

Key stage curriculum outcomes (KSCOs) align with the GCOs and summarize what students are expected to know and be able to do by the end of grade 12.

GCO 1 – STSE

By the end of grade 12, students will be expected to

- describe and explain disciplinary and interdisciplinary processes used to enable us to understand natural phenomena and develop technological solutions
- distinguish between science and technology in terms of their respective goals, products, and values, and describe the development of scientific theories and technologies over time
- analyze and explain how science and technology interact with and advance one another
- analyze how individuals, society, and the environment are interdependent with scientific and technological endeavours
- evaluate social issues related to the application and limitations of science and technology, and explain decisions in terms of advantages and disadvantages for sustainability, considering a variety of perspectives

GCO 2 – Skills

By the end of grade 12, students will be expected to

- ask questions about observed relationships and plan investigations of questions, ideas, problems, and issues
- conduct investigations into relationships between and among observable variables, and use a broad range of tools and techniques to gather and record data and information
- analyze data and apply mathematical and conceptual models to develop and assess possible explanations
- work as a member of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

GCO 3 – Knowledge

By the end of grade 12, students will be expected to

- analyze and describe relationships between force and motion
- analyze interactions within systems, using the laws of conservation of energy and momentum
- predict and explain interactions between waves and with matter, using the characteristics of waves
- explain the fundamental forces of nature, using the characteristics of gravitational, electric, and magnetic fields
- analyze and describe different means of energy transmission and transformation

GCO 4 - Attitudes

By the end of grade 12, students will be expected to

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- appreciate that the applications of science and technology can raise ethical dilemmas
- value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds
- show a continuing and more informed curiosity and interest in science and science-related issues
- acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research
- consider further studies and careers in science- and technology-related fields
- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations
- use factual information and rational explanations when analyzing and evaluating
- value the processes for drawing conclusions
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas
- have a sense of personal and shared responsibility for maintaining a sustainable environment
- project the personal, social, and environmental consequences of proposed action
- want to take action for maintaining a sustainable environment
- show concern for safety and accept the need for rules and regulations
- be aware of the direct and indirect consequences of their actions

Specific Curriculum Outcomes

Specific curriculum outcomes (SCOs) align to KSCOs and GCOs and describe what students should know and be able to do at the end of each course. They are intended to serve as the focus for the design of learning experiences and assessment tasks. SCOs are organized into units for each science course.

Course Overview

SCOs for Physics 3204 have been organized into five units:

- Integrated Skills
- Motion
- Forces
- Fields
- Introduction to Quantum Physics

Note, the *Integrated Skills* unit (Unit i) is not intended to be taught as a separate, stand alone unit.

Suggested Yearly Plan

The order in which the units are presented in the curriculum guide is the recommended sequence.

Unit 1 - Motion

Unit 2 - Forces

Unit 3 - Fields

Unit 4 - Introduction to Quantum Physics

September	October	November	December	January	February	March	April	May	June
Unit 1: Motion		Unit 2: Forces			Unit 3: Fields				Unit 4: Introduction to Quantum Physics
Skills Integrated Throughout									

How to Use the Four Column Curriculum Layout

Outcomes

Column one contains specific curriculum outcomes (SCO) and accompanying delineations where appropriate. The delineations provide specificity in relation to key ideas.

Outcomes are numbered in ascending order

Delineations are indented and numbered as a subset of the originating SCO.

All outcomes are related to general curriculum outcomes.

Focus for Learning

Column two is intended to assist teachers with instructional planning. It also provides context and elaboration of the ideas identified in the first column.

This may include:

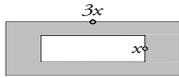
- references to prior knowledge
- clarity in terms of scope
- depth of treatment
- common misconceptions
- cautionary notes
- knowledge required to scaffold and challenge student's learning

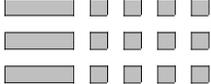
Sample Performance Indicator(s)

This provides a summative, higher order activity, where the response would serve as a data source to help teachers assess the degree to which the student has achieved the outcome.

Performance indicators are typically presented as a task, which may include an introduction to establish a context. They would be assigned at the end of the teaching period allocated for the outcome.

Performance indicators would be assigned when students have attained a level of competence, with suggestions for teaching and assessment identified in column three.

SPECIFIC CURRICULUM OUTCOMES	
<i>GCO 1: Represent algebraic expressions in multiple ways</i>	
<p>Outcomes</p> <p><i>Students will be expected to</i></p> <p>1.0 <i>model, record and explain the operations of multiplication and division of polynomial expressions (limited to polynomials of degree less than or equal to 2) by monomials, concretely, pictorially and symbolically. [GCO 1]</i></p> <p>1.2 <i>model division of a given polynomial expression by a given monomial concretely or pictorially and record the process symbolically.</i></p> <p>1.3 <i>apply a personal strategy for multiplication and division of a given polynomial expression</i></p>	<p>Focus for Learning</p> <p>From previous work with number operations, students should be aware that division is the inverse of multiplication. This can be extended to divide polynomials by monomials. The study of division should begin with division of a monomial by a monomial, progress to a polynomial by a scalar, and then to division of a polynomial by any monomial.</p> <p>Division of a polynomial by a monomial can be visualized using area models with algebra tiles. The most commonly used symbolic method of dividing a polynomial by a monomial at this level is to divide each term of the polynomial by the monomial, and then use the exponent laws to simplify. This method can also be easily modelled using tiles, where students use the sharing model for division.</p> <p>Because there are a variety of methods available to multiply or divide a polynomial by a monomial, students should be given the opportunity to apply their own personal strategies. They should be encouraged to use algebra tiles, area models, rules of exponents, the distributive property and repeated addition, or a combination of any of these methods, to multiply or divide polynomials. Regardless of the method used, students should be encouraged to record their work symbolically. Understanding the different approaches helps students develop flexible thinking.</p> <p>Sample Performance Indicator</p> <p>Write an expression for the missing dimensions of each rectangle and determine the area of the walkway in the following problem:</p> <ul style="list-style-type: none"> • The inside rectangle in the diagram below is a flower garden. The shaded area is a concrete walkway around it. The area of the flower garden is given by the expression $2x^2 + 4x$ and the area of the large rectangle, including the walkway and the flower garden, is $3x^2 + 6x$. 

SPECIFIC CURRICULUM OUTCOMES	
<i>GCO 1: Represent algebraic expressions in multiple ways</i>	
<p>Sample Teaching and Assessment Strategies</p> <p>Teachers may use the following activities and/or strategies aligned with the corresponding assessment tasks:</p> <p>Modeling division using the sharing model provides a good transition to the symbolic representation. For example, $\frac{3x+12}{3} = \frac{3x}{3} + \frac{12}{3}$. To model this, students start with a collection of three x-tiles and 12 unit tiles and divide them into three groups.</p>  <p>For this example, $x + 4$ tiles will be a part of each group, so the quotient is $x + 4$.</p> <p>Activation</p> <p>Students may</p> <ul style="list-style-type: none"> Model division of a polynomial by a monomial by creating a rectangle using four x^2-tiles and eight x-tiles, where $4x$ is one of the dimensions. <p>Teachers may</p> <ul style="list-style-type: none"> Ask students what the other dimension is and connect this to the symbolic representation. <p>Connection</p> <p>Students may</p> <ul style="list-style-type: none"> Model division of polynomials and determine the quotient <ol style="list-style-type: none"> $(6x^2 + 12x - 3) \div 3$ $(4x^2 - 12x) \div 4x$ <p>Consolidation</p> <p>Students may</p> <ul style="list-style-type: none"> Draw a rectangle with an area of $36a^2 + 12a$ and determine as many different dimensions as possible. <p>Teachers may</p> <ul style="list-style-type: none"> Discuss why there are so many different possible dimensions. <p>Extension</p> <p>Students may</p> <ul style="list-style-type: none"> Determine the area of one face of a cube whose surface area is represented by the polynomial $24s^2$. Determine the length of an edge of the cube. 	<p>Resources and Notes</p> <p>Authorized</p> <ul style="list-style-type: none"> <i>Math Makes Sense 9</i> Lesson 5.5: Multiplying and Dividing a Polynomial by a Constant Lesson 5.6: Multiplying and Dividing a Polynomial by a Monomial ProGuide: pp. 35-42, 43-51 CD-ROM: Master 5.23, 5.24 See It Videos and Animations: <ul style="list-style-type: none"> Multiplying and Dividing a Polynomial by a Constant, Dividing Multiplying and Dividing a Polynomial by a Monomial, Dividing SB: pp. 241-248, 249-257 PB: pp. 206-213, 214-219

Resources and Notes

Column four references supplementary information and possible resources for use by teachers.

These references will provide details of resources suggested in column two and column three.

Suggestions for Teaching and Assessment

This column contains specific sample tasks, activities, and strategies that enable students to meet the goals of the SCOs and be successful with performance indicators. Instructional activities are recognized as possible sources of data for assessment purposes. Frequently, appropriate techniques and instruments for assessment purposes are recommended.

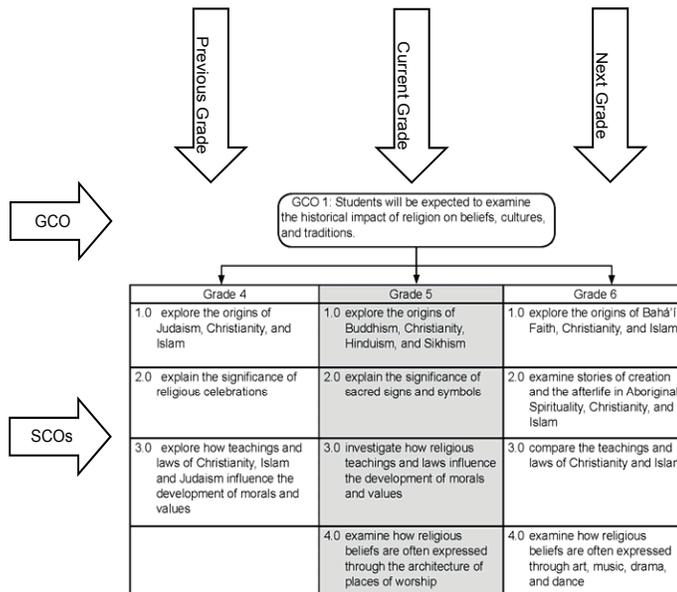
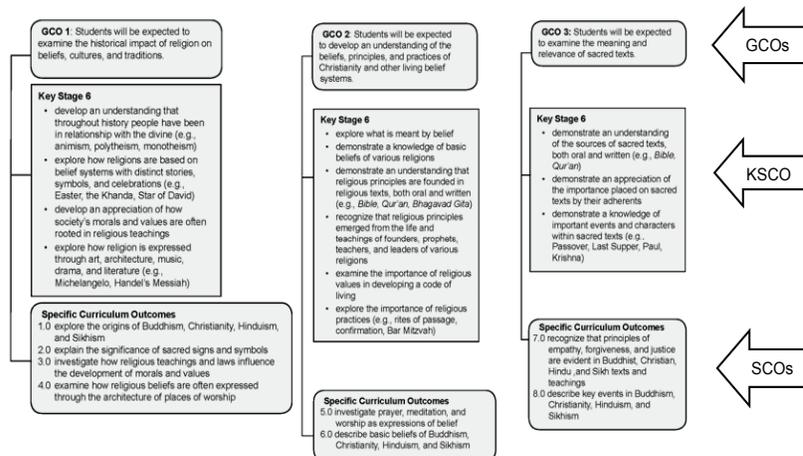
Suggestions for instruction and assessment are organized sequentially:

- **Activation** - suggestions that may be used to activate prior learning and establish a context for the instruction
- **Connection** - linking new information and experiences to existing knowledge inside or outside the curriculum area
- **Consolidation** - synthesizing and making new understandings
- **Extension** - suggestions that go beyond the scope of the outcome

These suggestions provide opportunities for differentiated learning and assessment.

How to use a Strand overview

At the beginning of each strand grouping there is explanation of the focus for the strand and a flow chart identifying the relevant GCOs, KSCOs and SCOs.



The SCOs Continuum follows the chart to provide context for teaching and assessment for the grade/course in question. The current grade is highlighted in the chart.

Section Three: Specific Curriculum Outcomes

Unit i - Integrated Skills

Focus

Students use a variety of skills when investigating questions, ideas, problems, and issues. While these skills are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations.

The listing of skills is not intended to imply a linear sequence or to identify a single set of skills required in each science investigation. Every investigation has unique features that determine the particular mix and sequence of skills.

Four broad areas of skills are outlined and developed:

- Initiating and Planning - These are the skills of questioning, identifying problems, and developing initial ideas and plans.
- Performing and Recording - These are the skills of carrying out action plans, which involves gathering evidence by observation and, in most cases, manipulating materials and equipment.
- Analyzing and Interpreting - These are the skills of examining information and evidence, of processing and presenting data so that it can be interpreted, and interpreting, evaluating, and applying the results.
- Communication and Teamwork - In science, communication skills are essential at every stage where ideas are being developed, tested, interpreted, debated, and agreed upon. Teamwork skills are also important, since the development and application of science ideas is a collaborative process both in society and in the classroom.

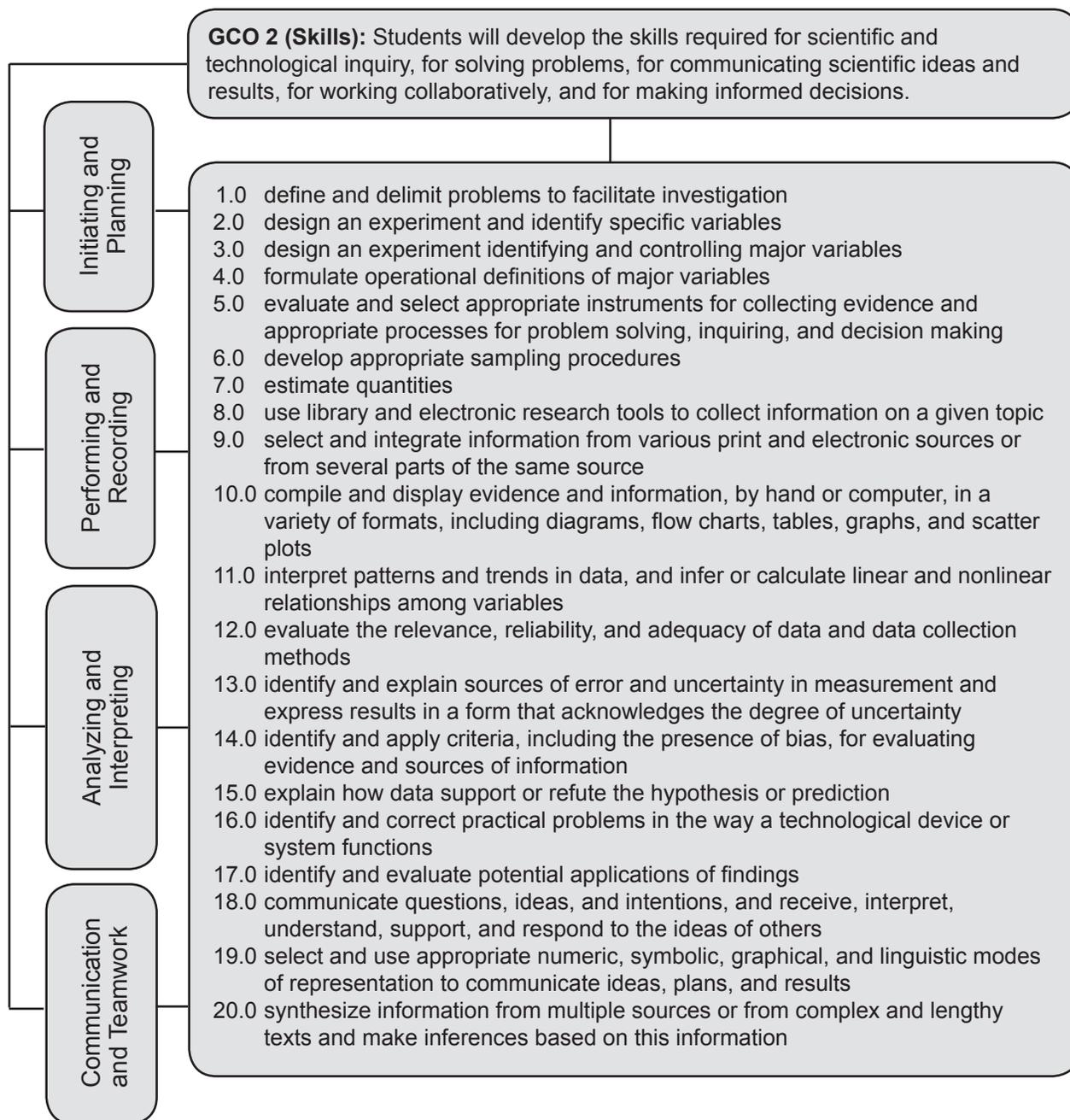
Students should be provided with opportunities to develop and apply their skills in a variety of contexts. These contexts connect to the STSE component of the curriculum by linking to three processes for skills application:

- Science inquiry - seeking answers to questions through experimentation and research.
- Problem solving - seeking solutions to science-related problems by developing and testing prototypes, products, and techniques to meet a given need.
- Decision making - providing information to assist the decision making process.

Unit i - Integrated Skills

Unit i, the *Integrated Skills* unit, appears at the beginning of this curriculum guide. A total of 43 skill outcomes are identified and addressed throughout high school science courses, however, not all skills appear in every curriculum guide or course. In Physics 3204, students are expected to develop proficiency with respect to 20 skills; these are listed in the outcomes framework.

Outcomes Framework



SCO Skill Continuum

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

Science 7-9	Science 10-12
<ul style="list-style-type: none"> rephrase questions in a testable form and clearly define practical problems define and delimit questions and problems to facilitate investigation 	<ul style="list-style-type: none"> define and delimit problems to facilitate investigation
<ul style="list-style-type: none"> design an experiment and identify major variables 	<ul style="list-style-type: none"> design an experiment and identify specific variables design an experiment identifying and controlling major variables
<ul style="list-style-type: none"> formulate operational definitions of major variables and others aspects of their investigations 	<ul style="list-style-type: none"> formulate operational definitions of major variables
<ul style="list-style-type: none"> select appropriate methods and tools for collecting data and information and for solving problems 	<ul style="list-style-type: none"> evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making
	<ul style="list-style-type: none"> develop appropriate sampling procedures
<ul style="list-style-type: none"> estimate measurements 	<ul style="list-style-type: none"> estimate quantities
<ul style="list-style-type: none"> select and integrate information from various print and electronic sources or from several parts of the same source 	<ul style="list-style-type: none"> use library and electronic research tools to collect information on a given topic select and integrate information from various print and electronic sources or from several parts of the same source
<ul style="list-style-type: none"> compile and display data, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, bar graphs, line graphs, and scatter plots 	<ul style="list-style-type: none"> compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
<ul style="list-style-type: none"> interpret patterns and trends in data, and infer and explain relationships among the variables 	<ul style="list-style-type: none"> interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
	<ul style="list-style-type: none"> evaluate the relevance, reliability, and adequacy of data and data collection methods
<ul style="list-style-type: none"> identify potential sources and determine the amount of error in measurement 	<ul style="list-style-type: none"> identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty

SCO Skill Continuum

Science 7-9	Science 10-12
<ul style="list-style-type: none"> • apply given criteria for evaluating evidence and sources of information 	<ul style="list-style-type: none"> • identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information
<ul style="list-style-type: none"> • state a conclusion, based on experimental data, and explain how evidence gathered supports or refutes an initial idea 	<ul style="list-style-type: none"> • explain how data support or refute the hypothesis or prediction
<ul style="list-style-type: none"> • identify and correct practical problems in the way a prototype or constructed device functions 	<ul style="list-style-type: none"> • identify and correct practical problems in the way a technological device or system functions
<ul style="list-style-type: none"> • identify and evaluate potential applications of findings 	<ul style="list-style-type: none"> • identify and evaluate potential applications of findings
<ul style="list-style-type: none"> • receive, understand, and act on the ideas of others • communicate questions, ideas, intentions, plans, and results, using lists, notes in point form, sentences, data tables, graphs, drawings, oral language, and other means 	<ul style="list-style-type: none"> • communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others • select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
	<ul style="list-style-type: none"> • synthesize information from multiple sources or from complex and lengthy texts and make inferences based on this information

Suggested Unit Plan

The Integrated Skills unit is not intended to be taught as a separate, stand alone unit. Rather, as skill outcomes [GCO 2] are encountered in Units 1-4, teachers should refer out to the focus for learning elaborations and teaching and assessment suggestions provided in this unit.

Skill outcomes should be integrated throughout all content units. Provide opportunities for students to develop and apply these skills in varied contexts:

- Science Inquiry - seeking answers to questions through experimentation and research
- Problem Solving - seeking solutions to science-related problems by developing and testing prototypes, products, and techniques to meet a given need
- Decision Making - providing information to assist the decision making process

The inclusion of science projects is strongly recommended to address and assess skill outcomes.

September	October	November	December	January	February	March	April	May	June
Unit 1: Motion		Unit 2: Forces			Unit 3: Fields			Unit 4: Introduction to Quantum Physics	
Skills Integrated Throughout									

Initiating and Planning

Outcomes

Students will be expected to

1.0 define and delimit problems to facilitate investigation [GCO 2]

2.0 design an experiment and identify specific variables [GCO 2]

3.0 design an experiment identifying and controlling major variables [GCO 2]

Focus for Learning

Students should ask questions about observed relationships and plan investigations of questions, ideas, problems, and issues (p. 21). Six initiating and planning skills aligned with this GCO are included in the Physics 3204 curriculum guide.

When initiating and planning scientific or research inquiry, defining and delimiting problems is an integral skill. This skill is employed when students attempt to move from a general research area of interest to a specific research question. Students may have prior experience with this skill, particularly if they participated in science fairs.

Students should be expected to formulate research questions from areas of interest. Narrowing a research focus to facilitate investigation of a question involves defining and delimiting the problem. Students should

- attempt to understand the nature of a problem (i.e., What are the variables of influence? What are the relationships among the variables);
- delimit the problem (i.e., What will be the scope of the research? What are the boundaries? What theoretical perspective will be used? Which variables will be investigated?); and
- formulate a research question, state a hypothesis consistent with the theoretical perspective, formulate operational definitions of the major variables, and devise a procedure.

Differentiate between the terms limit and delimit. Delimiting is the thoughtful process researchers employ to narrow their research focus (i.e., what they will and will not investigate and why).

SCOs 2.0 and 3.0 are similar outcomes. Both expect students to design experiments and identify variables. SCO 3.0 also expects the experimental design to control major confounding variables.

Students have prior experience designing experiments to determine relationships among variables. They should

- identify and define the dependent, independent, and control variables;
- formulate the inquiry question to investigate;
- design an experiment to generate relevant data; and
- devise a procedure that controls potential confounding variables.

Additionally, students should evaluate the designs of others' experiments to identify the inquiry question and major variables, and assess whether confounding variables are controlled.

These initiating and planning skills are addressed in multiple units. Students design investigations, for example, to determine coefficient of kinetic friction for an inclined plane (SCO 2.0) and determine the effect of initial speed and launch height on the range of a projectile launched horizontally (SCO 3.0).

Initiating and Planning

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Provide examples of visual representations of science inquiry processes. Ask students to note similarities in their stages.

Connection

Teachers may

- Present a general research topic (e.g., electromagnetic radiation) and explicitly model how the topic might be narrowed down into a specific research question.
- Distinguish between the terms limiting and delimiting.
- Present students with general research topics and ask them to provide examples of how they might delimit the topic to facilitate research.
- Provide research questions and ask students to identify the independent and dependent variables, as well as confounding variables that would need to be controlled.
- Collaboratively design an experiment with students as an exemplar.

Students may

- Review abstracts of scientific investigations as exemplars of how problems are defined and delimited to facilitate investigation and how major variables are identified and controlled.
- Select an Inquiry Lab from *Pearson Physics* and identify the major variables.
- Review labs carried out in Physics 2204 and identify the major variables.

Consolidation

Teachers may

- Provide a research question and ask students to design an experiment to answer the question while controlling possible confounding variables.

Students may

- Design an experiment to determine
 - acceleration of an object dropped from various heights.
 - the affect of surface area on objects in free fall.
- To fulfill requirements of a science project, define and delimit a problem and design an investigation to answer the problem.

Resources and Notes

Authorized

Pearson Physics (Student Resource [SR])

- pp. 864-866

Pearson Physics 20 and 30 (Teacher Resource [TR])

- Assessment Rubric GR 5: Design a Lab Process

Initiating and Planning

Outcomes

Students will be expected to

- 4.0 formulate operational definitions of major variables
[GCO 2]

- 5.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making
[GCO 2]

Focus for Learning

Formulating operational definitions of variables is an integral skill when designing experiments. Operational definitions are procedural statements specific to each investigation. They define the process used to determine the nature of major variables and their properties.

When designing an investigation to determine the effect of launch height on the range of a projectile fired horizontally, for example, students operationally define the launch height and range:

- What launch heights will be tested?
- What instruments, units, and procedures will be used to measure height and range?
- How many trials will be conducted for each height?
- What statistical treatments will be applied to the collected data?
- What controls will be put in place?

Note, different student groups, investigating the same inquiry question, may operationally define the same variables in different ways.

This skill is first addressed in the projectile motion investigations where students formulate operational definitions for speed, launch height, and range. It is also addressed when they investigate factors (i.e., number of loops in the coil, coil diameter, coil density, magnet strength, relative speed of motion between the magnet and coil) that influence the effect produced when there is relative motion between an external magnetic field and a conducting wire.

When problem solving, inquiring, and decision making, students should evaluate and select instruments and processes for collecting evidence. While students have prior experience with scientific inquiry, problem solving, and decision making processes, a review of these processes, and their associated methodologies, is warranted.

Often, procedures with predetermined instruments and processes are provided to students. To meet the expectation of this outcome, however, students should personally evaluate and select appropriate instruments and procedures, when planning investigations. Students should

- identify the evidence required to answer the inquiry question, solve the problem, or inform decision making;
- select an appropriate process to collect the required evidence; and
- select an appropriate instrument to collect the required evidence.

When evaluating and selecting appropriate analog and digital instruments, students should consider the degree of precision and accuracy required. They should be able to explain and defend their choice of instruments and processes for collecting evidence.

This skill is first addressed in Unit 2. Students evaluate and select instruments and processes when designing an investigation to determine the coefficient of kinetic friction for an inclined plane.

Initiating and Planning

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Provide visual representations of science inquiry, problem solving, and decision making processes.
- Demonstrate use of a multimeter for measuring current, voltage, and resistance. Emphasize the importance of proper ranging and other functions.

Connection

Teachers may

- Distinguish between a definition and an operational definition.
- Revisit the Physics 2204 lab in which students investigated to determine the spring constant, k for a variety of springs. Discuss how they operationally defined mass and displacement (i.e., spring stretch).
- Present published scientific investigations and ask students to describe how the major variables are operationally defined.
- Distinguish between science inquiry, problem solving, and decision making processes.
- Where possible, provide a collection of different analog and digital instruments for students to choose from when investigating.

Students may

- Select and review an Inquiry Lab from *Pearson Physics*. Describe how the major variables are operationally defined within the lab.
- Suggest alternative ways to operationally define major variables within an investigation.

Consolidation

Teachers may

- Provide a research question and ask students to indicate the appropriate processes (e.g., inquiry, problem solving, decision making) and instruments needed to collect required evidence.

Students may

- Formulate operational definitions for major variables when designing an experiment and devising procedures (e.g., science project).
- Evaluate potential instruments for collecting evidence to determine resultant displacement. Select an instrument and justify your choice.
- Evaluate and select appropriate instruments when collecting evidence from electric circuits (e.g., ammeter, galvanometer, voltmeters).

Resources and Notes

Authorized

Pearson Physics (SR)

- pp. 864-866

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5: Design a Lab Process

Initiating and Planning

Outcomes

Students will be expected to

- 6.0 develop appropriate sampling procedures [GCO 2]

Focus for Learning

When planning investigations, developing appropriate sampling procedures (i.e., sample selection, measurement, and analysis procedures) is critical. Sampling procedures significantly impact the quality of results obtained from investigations. This outcome was addressed in Science 1206 and in Physics 2204, students implemented appropriate sampling procedures.

To meet the expectation of this outcome, students should determine the evidence needed to answer their question and develop appropriate sampling procedures to collect it. When investigating how initial speed and launch height affect the range of a projectile launched horizontally, for example, students should ask:

- How many launch heights and initial speeds will be tested?
- How will range be measured (i.e., instrument, unit, sampling technique)?
- How many samples are required?
- What data treatments will be applied to samples?.

Students should conduct multiple trials to minimize error. Additionally, if ten trials are conducted, for example, then the smallest and the largest values may be dropped and the mean of the remaining eight values calculated.

Developing appropriate sampling procedures is addressed in multiple units. Students should understand that sampling procedures are an important aspect of investigations; having significant impact on the quality of evidence collected. Determining what procedures are appropriate is a skill that develops over time as students are increasingly exposed to investigations within the discipline.

Initiating and Planning

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Distinguish between probability and non-probability sampling design in research.
- Discuss with students possible limitations of sampling procedures (e.g., bias, sample size, sampling error).
- Present published scientific investigations and ask students collaboratively identify the sampling procedures and techniques employed.

Students may

- Select and review an Inquiry Lab from *Pearson Physics*. Describe the sampling procedures and techniques employed.
- Describe in detail the sampling techniques employed when using an instrument to collect evidence (e.g., galvanometer, measuring tape, motion sensor, voltmeter).

Consolidation

Teachers may

- Provide a research question and ask students to develop appropriate sampling procedures to collect the evidence required to answer the question.

Students may

- Develop appropriate sampling procedures when designing an experiment and devising procedures (e.g., science project).
- Evaluate the appropriateness of sampling procedures in experimental procedures and suggest modification to reduce sampling error.

Resources and Notes

Authorized

Pearson Physics (SR)

- pp. 864-866

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5:
Design a Lab Process

Performing and Recording

Outcomes

Students will be expected to

7.0 estimate quantities
[GCO 2]

Focus for Learning

Students should conduct investigations into relationships among observable variables, and use a broad range of tools and techniques to gather and record data and information (p. 21). Three performing and recording skills aligned with this GCO are included in the Physics 3204 curriculum guide.

Students should estimate quantities when measuring, compiling, and recording data. Estimating quantities is useful when

- selecting a measurement instrument with sufficient capacity,
- obtaining precise quantities is impractical,
- approximated quantities are sufficient for the task, and
- used as a rough check of the accuracy (i.e., reasonableness) of calculated values.

Students have experience estimating and calculating exact values in mathematics and experience estimating uncertain digits when using measuring tools and instruments in science courses. When measuring, students should always record all certain digits and estimate the first uncertain digit.

Estimation in science also includes

- extrapolating and interpolating from graphs or data sets,
- guess and check estimation in calculations, and
- trial and error in problem solving.

This skill is first applied during the Unit 1 vector walk when students estimate measurements and calculations. In Unit 2 students explore finding the balance point between masses hung on opposite ends of a metre stick. They estimate when

- attempting to find the balance point,
- measuring the distance from the pivot, and
- calculating weight and torque.

Performing and Recording

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Facilitate a discussion regarding situations when we use estimation in daily life (e.g., estimating temperature, total cost of a set of items, wait times).

Connection

Teachers may

- Explicitly instruct students to record all certain digits and estimate the first uncertain digit when measuring.
- Recommend that students take digital images of analog instrument measurements and enlarge them to improve estimates of the first uncertain digit.
- Where possible, provide collections of similar instruments with varying scales. Ask students to estimate values and select the instrument with the most appropriate scale, based on their estimate.

Students may

- Estimate angle measurements, distances, forces, and masses and use appropriate instruments to measure them and assess the accuracy of their initial estimate.
- Given a data table or graph, estimate the value or a quantity using interpolation or extrapolation.

Resources and Notes

Authorized

Pearson Physics (SR)

- pp. 875-879

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5:
Design a Lab Process

Performing and Recording

Outcomes

Students will be expected to

8.0 use library and electronic research tools to collect information on a given topic [GCO 2]

9.0 select and integrate information from various print and electronic sources or from several parts of the same source [GCO 2]

Focus for Learning

These skills were previously addressed in Physics 2204.

Students should use a broad range of research inquiry tools and techniques to gather information when investigating questions, ideas, problems, and issues.

Review relevant acceptable use of library and electronic research tools, practices, and policies. Students will continue to develop practical skills necessary to evaluate the validity, reliability, and bias of a source. They should determine origin of material and check sources for age appropriateness, organized links, and important and accessible information. They should also be able to use advanced search techniques and keywords.

A review of the following may be necessary:

- Acceptable types of information and sources
- Citation and reference guidelines
- Rules regarding plagiarism

Students should continue to develop strategies related to selecting, organizing, and integrating information that is gathered through research.

To help with organization, students may

- assign a number or letter to indicate relevance;
- keep track of citation while organizing and writing;
- organize materials they have read;
- paraphrase and summarize;
- categorize research into sub-topics;
- use graphic organizers, diagrams, flow charts, tables, and graphs;
- use notes to generate questions and ideas; and
- write jot notes or highlight information as they read.

These skill outcomes are addressed in Unit 3 when students research artificial satellites. They should be addressed and assessed, however, whenever students engage in research inquiry.

Performing and Recording

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review research and citing protocol.
- Invite a representative from the Newfoundland and Labrador Public Libraries (NLPL) to provide an over view of NLPL services and databases. Request library cards for students.

Students may

- Discuss topics from previous science courses on which they or their classmates conducted research.
- Discuss the importance of having reliable and valid sources when conducting research (a reliable source may not be valid).

Connection

Teachers may

- Initiate a classroom discussion on why certain online sites are not considered to be reliable sources. Discuss the importance of fact-checking for social-media based information as well as the benefits of peer reviewed sources for research.

Students may

- Demonstrate various sources of reliable information such as e-library and questionable sources such as social media.
- Organize the information collected when researching. For example, organize information regarding the electromagnetic field produced by high voltage power lines and possible effects.

Consolidation

Students may

- Conduct research inquiry to develop arguments for or against a proposal to construct a high voltage power line adjacent to a local high school.
- Use research inquiry to investigate geosynchronous satellite technologies.
- Use research inquiry to collect the information required to develop a research abstract for a science fair project.

Resources and Notes

Authorized

Pearson Physics (SR)

- pp. 864-866

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 11: Research Report

Analyzing and Interpreting

Outcomes

Students will be expected to

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
[GCO 2]

Focus for Learning

Students should analyze data and apply mathematical and conceptual models to develop and assess possible explanations (p. 21). Eight analyzing and interpreting skills aligned with this GCO are included in the Physics 3204 curriculum.

Students should compile and display data and information from scientific and research investigations in a variety of formats:

- Diagrams are used to symbolically represent information.
- Flow charts are used to represent a process.
- Tables organize data and information into labelled columns and rows.
- Graphs (e.g., bar, histogram, pictograph, line) help visualize relationships in data.
- Scatter plots are used to determine the degree of correlation between variables.

Students should select the most appropriate format to represent their data and information and, where possible, use digital technologies in their creation. Representations should be clear, concise, and include titles, headings, labels, scales, units, symbols, and numbers, where appropriate. Accurate representation of data and information is paramount to facilitate analysis and interpretation, identify patterns and trends, and infer or calculate relationships among variables.

This skill outcome is first addressed as part of the projectile motion labs. However, it should be assessed whenever students conduct investigations. While formats such as tables, graphs, and scatter plots are often the focus of this outcome, however, displaying information in vector and free-body diagrams should also be a focus.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Review appropriate use of diagrams, flow charts, tables, bar graphs, line graphs, and scatter plots.
- Review requirements for drawing vector and free body diagrams.
- Set clear expectations for the construction of diagrams, tables, graphs, and scatter plots.
- Highlight and discuss common graphing errors (e.g., selecting an inappropriate graph type for the data, placing variables on the wrong axes, use of inappropriate scales).
- Provide a set of unorganized data or information and ask students to compile and display it in appropriate formats.

Students may

- Justify selection of a particular format to compile and display data from an investigation. Initially guide students in graphing data from early investigations. As the material progresses, make the interpretation more of a student responsibility.

Consolidation

Teachers may

- Allow students to choose a format to compile and display their evidence and information, rather than prescribing one.
- Require students to submit their compiled and displayed results for assessment, after completion of lab investigations.

Students may

- Construct vector, free body, and circuit diagrams to display information.
- Compile and display data and information from class investigations and science projects using a variety of digital technologies.

Resources and Notes

Authorized

Pearson Physics (SR)

- pp. 864-866
- pp. 869-874

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5: Design a Lab Process
- Assessment Rubric GR 6: Graphical Analysis Techniques

Analyzing and Interpreting

Outcomes

Students will be expected to

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
[GCO 2]

Focus for Learning

Students should analyze data and apply mathematical models to develop and assess possible explanations. Analyzing data includes interpreting trends and patterns, and inferring or calculating relationships:

- A trend is the general tendency of a data set to change. While individual data points may vary, the overall data trends in one direction.
- Patterns refer to data or information that repeat in a predictable way.
- Relationships are similar to trends, but have a clear mathematical relationship (e.g., linear relationship).

Identifying trends, patterns, and relationships requires accurate representation of data in tables, graphs, and scatter plots.

Students should

- infer linear and nonlinear relationships from data and representations, and
- calculate the slope of linear relationships and determine the equation of the line of best fit.

This skill is first addressed when students investigate to determine the affect of speed on radius and centripetal force. It is also addressed in the circuits lab, determining the relationships between resistance, voltage, and current, and when students investigate factors that influence the effect produced when there is relative motion between an external magnetic field and a conducting wire.

This outcome should be assessed whenever students analyze and interpret data from investigations. Where possible, computers and digital tools should be used to enhance analysis and interpretation.

Note, students should be cautioned about interpreting patterns and trends in data and inferring and calculating relationships based on inadequate sample sizes.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present exemplars of data tables and graphs illustrating typical patterns and trends, including linear and non-linear relationships.
- Model interpreting patterns and trends in data and inferring and calculating linear and non-linear relationships among variables.

Students may

- Draw lines of best fit by hand and compare with those identified using digital technologies.

Consolidation

Teachers may

- Present graphs and ask students to
 - explain what the graph is communicating,
 - interpolate and extrapolate information,
 - identify patterns or trends, and
 - infer relationships among variables, and calculate, when possible, linear and non-linear relationships.

Students may

- Interpret patterns and trends, and infer and calculate relationships, in data compiled and displayed as part of class investigations and science projects.

Resources and Notes

Authorized

Pearson Physics (SR)

- pp. 864-866
- pp. 872-874

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5: Design a Lab Process
- Assessment Rubric GR 6: Graphical Analysis Techniques

Analyzing and Interpreting

Outcomes

Students will be expected to

12.0 evaluate the relevance, reliability, and adequacy of data and data collection methods
[GCO 2]

13.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty
[GCO 2]

Focus for Learning

Students should evaluate data and data collection methods with respect to

- relevance (i.e., Does the collected data help answer the initial question?);
- reliability (i.e., Can the data and findings be replicated?); and
- adequacy (i.e., Is the quality and quantity of the data sufficient to draw a conclusion?).

Students should recognize that use of inappropriate data collection methods, sampling procedures, and measurement instruments, may result in irrelevant, unreliable, or inadequate evidence. They should suggest modifications to investigations to improve the data and data collection methods.

Students will often experience outliers in data when conducting physics experiments. They should recognize outliers and identify reasons for their exclusion from data analysis.

This skill is specifically addressed when investigating Kirchhoff's current and voltage laws in series and parallel circuits. It should be assessed, however, whenever students collect data as part of an investigation.

Error and uncertainty exist in every measurement, but, with care and refinement of experimental methods, they can be reduced. Students should identify and explain sources of error in measurements, including systematic and random errors.

Systematic errors consistently cause measurements to be too high or too low. They may be caused by faulty or inaccurate measurement tools and instruments or their incorrect use. While difficult to identify, systematic errors can be eliminated. Random error in measurement occurs without a pattern. Estimates will sometimes be too high and other times too low. These errors may be reduced by repeating trials and using average measurements, or increasing sample size.

Students should express data and results in a form that acknowledges the degree of uncertainty. They should use the appropriate number of significant figures as indicated by the measuring device and apply significant figure rules in calculations. Rules for their use can be found in Appendix A (pp. 168-170).

Teachers should note that scientific notation is not addressed in the existing Mathematics program.

This outcome is first addressed when students carry out a vector walk in Unit 1 using a personally selected measurement tools. It should be assessed, however, whenever students take measurements as part of an investigation.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Use political polling as the context to discuss sampling and the relevance, reliability, and adequacy of data and data collection methods. Discuss examples of inaccurate polling when compared to actual election results.

Connection

Teachers may

- Review what is meant by relevance, reliability, and adequacy of data and data collection methods and provide examples of irrelevant, unreliable, and inadequate data and methods.
- Present published scientific investigations and collaboratively evaluate the data and data collection methods.
- Demonstrate and discuss possible source of error when using specific tools and instruments for measurement.
- Differentiate between random and systematic errors.
- Discuss outliers and rationale for their exclusion from data analysis.

Students may

- Review student lab reports and evaluate their data and data collection methods for relevance, reliability and adequacy.
- Identify examples of potential random and systematic errors when using specific measuring tools and instruments (e.g., force meter, multimeter, protractor, ruler).
- View video of classmates carrying out investigations to identify sources of error.
- View digital images of measurements using analog instruments and discuss how the results should be expressed.
- Measure a distance using a variety of instruments (e.g., ruler, meter stick, trundle wheel, construction measuring tape). Compare the results obtained using the different instruments and discuss the precision and reliability of measurement.

Consolidation

Teachers may

- Require students to examine and comment on sources of error when writing conclusions for investigations.

Students may

- Identify and explain ways to reduce errors in investigations.

Resources and Notes

Authorized

Appendices

- Appendix A

Pearson Physics (SR)

- pp. 864-866
- pp. 872-877

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5: Design a Lab Process

Analyzing and Interpreting

Outcomes

Students will be expected to

14.0 identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information
[GCO 2]

15.0 explain how data support or refute the hypothesis or prediction
[GCO 2]

Focus for Learning

When engaged in research inquiry, information may be obtained from a variety of sources. However, not all information is reliable. Students should critically evaluate the reliability of each information source.

If the information source is scholarly, they should consider the following:

- Is the information supported by evidence which is referenced?
- Has the content been peer-reviewed or edited by a publisher?
- Can the information be verified by other scholarly literature?

If the information source is non-scholarly, they should consider the following:

- Who is the author? What are their credentials? Are their credentials visible? Are they affiliated with a recognized research institution?
- What is the purpose of the work? Why was it written? Who is the audience? What is the message?
- Is the work sponsored by a company or special interest group?
- Is the work biased?

This skill should also be applied to the evaluation of scientific research.

English Language Arts curricula provide excellent outlines of how to deal with sources of information.

Analysis and interpretation of data should culminate in a statement explaining the results of the investigation. This conclusion should refer back to the initial hypothesis and explain whether the results support, partially support, or refute the hypothesis.

Additionally, the conclusion should

- examine and comment on sources of error and uncertainty,
- assess the effectiveness of the investigative design,
- suggest applications of findings, and
- propose new questions to investigate.

This skill is addressed in Unit 2 when students investigate the affect of speed on radius and centripetal force and Unit 3 when they explore Kirchhoff's current and voltage laws. The outcome should also be addressed, however, whenever students make hypotheses and predictions as part of investigations.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Provide detailed criteria for evaluating evidence and sources of information.
- Discuss the reliability of science-related claims found in advertising and social media.
- Present science-related articles obtained from various information sources (e.g., journals, science magazines, websites, social media) and ask students to apply criteria to evaluate the reliability of the information.
- Discuss how evidence may support or refute the hypothesis, suggest revision of the initial hypothesis, or suggesting a new research question.
- Model, with the use of exemplars, how the interpretation of evidence may support or refute a hypothesis.

Students may

- Brainstorm possible sources of science information.
- Discuss the pros and cons of various media for communicating scientific findings.

Consolidation

Teachers may

- Present experimental data and ask students to analyze the data and explain whether it supports or refutes the hypothesis.
- Require students to explain how their data supports or refutes their hypothesis or prediction as part of the discussion section of lab reports.

Students may

- Compile a collection of physics-related articles and information pages from a variety of sources and apply criteria to evaluate the reliability of each source.
- Analyze and interpret collected evidence from investigations to determine whether it supports or refutes the hypothesis and provide an explanation in the discussion section of a lab report.

Resources and Notes

Authorized

Pearson Physics (SR)

- pp. 864-866

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5:
Design a Lab Process

Analyzing and Interpreting

Outcomes

Students will be expected to

16.0 identify and correct practical problems in the way a technological device or system functions [GCO 2]

17.0 identify and evaluate potential applications of findings [GCO 2]

Focus for Learning

The ability to identify and solve problems is a critical learning skill.

In Physics 3204, students use various technological devices (e.g., compass, force metre, stop watch, galvanometer, ammeter, voltmeter, multimeter, magnet, motion sensor) and systems (e.g., circuits, projectile launcher, torsion balance, UCM apparatus, simple generator, spread sheet applications) when investigating. Invariably, they will identify practical problems with the way devices and systems function (e.g., a force metre that can not be calibrated to zero due to overuse, a constructed circuit that is not working as intended, a multimeter with a blown fuse). In these situations students should identify and correct the problem.

This skill is first addressed in the projectile motion labs when students design and construct a horizontal projectile launcher from a collection of possible materials. The investigation of circuits also provides opportunities to address this skill. Additionally, this outcome should be assessed whenever students engage in design challenges (e.g., designing a simple generator to produce the strongest electric current).

The processes of scientific inquiry do not only lead to the development of scientific knowledge; they also change the way people live their daily lives through applications and the development of new technologies (i.e., products and processes).

Following scientific and research investigations, students should reflect on their findings and identify potential applications. They should evaluate these applications, considering the expected, unexpected, favourable, and unfavourable effects on society and the environment.

This skill is specifically addressed in Units 2 and 3. Students should, however, be expected to identify and evaluate potential applications or findings whenever they engage in scientific and research investigations.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Engage students, whenever possible, in investigations using physical materials and devices.
- During investigations, ask students whether they encountered any practical problems with the use of specific devices and how they corrected the problem.
- Identify problems with the way circuit functions and ask students to redesign the circuit to solve the problem.

Students may

- Analyze a technological device, identify problems, and suggest modifications that may improve the device.
- Correct for fluctuation in output current of a simple DC generator.

Consolidation

Teachers may

- Engage students in design challenges (e.g., construct a simple electric generator).
- Routinely ask students to identify potential applications of experimental findings and require that they be included in the discussion section of lab reports.

Students may

- Analyze the effects of new technological applications and classify effects as expected, unexpected, favourable, unfavourable.
- Participate in a science fair and consider the potential application of findings in the discussion section of the project write up.

Resources and Notes

Authorized

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5: Design a Lab Process

Communication and Teamwork

Outcomes

Students will be expected to

18.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
[GCO 2]

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
[GCO 2]

Focus for Learning

Students should work as a member of a team when investigating questions and addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results (p. 21). Three communication and teamwork skills aligned with this GCO are included in the Physics 3204 curriculum.

Scientists work in collaborative environments, surrounded by students and other scientists. They share ideas, help each other design experiments and studies, and sharpen each other's conclusions. Effective communication is critical to success. Students should

- effectively communicate their questions, ideas, and intentions, using appropriate scientific terminology;
- attentively receive and interpret the ideas of others;
- suspend judgement and respond to the ideas of others by asking clarifying questions to ensure understanding; and
- evaluate ideas, lending them support or constructive criticism.

Effectively sending and receiving information is an important learning skill. Communication skills should continue to be developed in all subject areas through a range of activities and strategies.

Effective science communication requires students to appropriately select and use numbers, symbols, diagrams, charts, tables, graphs, and oral and written language to communicate ideas, plans, and results.

Students should communicate using

- accurate numeric representations (e.g., scientific notation, appropriate number of significant figures) when measuring, calculating, and investigating;
- symbolic representations such as vectors, constants, formulas, and units;
- diagrams such as vector diagrams, free body diagrams, circuit diagrams, prototype sketches, apparatus set up, flow charts, and labelled data and information tables;
- labelled graphs, scatter plots, and lines of best fit; and
- oral and written language (e.g., communicating aloud questions, ideas, thoughts, and intentions when investigating, writing conclusions and lab reports, presenting and defending a position or course of action).

Virtually every stage of inquiry, problem solving, and decision making processes (i.e., initiating and planning, performing and recording, analyzing and interpreting) requires effective communication.

Communication and Teamwork

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Organize students in pairs and small groups, where possible, when carrying out investigations, problem solving, and decision making activities to encourage communication.
- Discuss and model what effective science communication looks and sounds like.
- Encourage students to think aloud while investigating.
- Request students digitally record their group communication when conducting investigations for assessment purposes.
- Provide guidelines for communicating in lab reports.
- Review requirements for effective communication using diagrams, flow charts, tables, and graphs.
- Provide opportunities for groups to communicate findings in formats of their choosing. Then, compare and discuss the effectiveness of different formats.
- Require students use appropriate numeric and symbolic representations when recording measures and formulas, and performing calculations.

Students may

- Collaboratively decide on rules for effective communication when working in groups.
- Show workings to effectively communicate solutions when solving problems mathematically.

Consolidation

Teachers may

- Assess student communication in
 - data displays,
 - mathematical problem solving,
 - diagrams (e.g., vector, free body, circuit)
 - presentations and debates, and
 - lab reports.

Students may

- Assess group communication when investigating.
- Use appropriate modes of representation to communicate experimental designs, hypotheses, personally devised procedures, measurements, displays of findings, and conclusions.

Resources and Notes

Authorized

Pearson Physics (SR)

- pp. 864-866
- pp. 869--877

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 5: Design a Lab Process
- Assessment Rubric GR 10: Teamwork

Communication and Teamwork

Outcomes

Students will be expected to

20.0 synthesize information from multiple sources or from complex and lengthy texts and make inferences based on this information
[GCO 2]

Focus for Learning

Information gathered from different sources can be synthesized to form a well-rounded explanation or argument. This skill will develop students' ability to determine relationships and connections among different sources. It is necessary for forming conclusions from pre-existing data. The results of synthesizing information will enable students to strengthen decision making and argumentation skills. It will also strengthen students' ability to make inferences and offer plausible explanations.

In developing this skill, it may be necessary to begin with simple, limited sources. Further development may increase the level of complexity of sources, or the number of sources from which information can be gathered. Teachers should emphasize the importance of evaluating sources in terms of accuracy and reliability.

This skill is specifically addressed and assessed in conjunction with synthesizing information. Students may develop an argument, position or plan of action. This will develop deep critical thinking skills, abstract thinking and communication skills through presenting, debating or defending.

Teachers may provide an opportunity for students to present their position as well as the positions of others, and offer rebuttals. It is best to provide a structured lesson (e.g., debate, role playing, four corners, debate line) in which teachers can facilitate and moderate such activities.

Opportunities to present in the science classroom are important for developing communication skills and may be used cross-curricularly to assess English Language Arts outcomes.

Communication and Teamwork

Sample Teaching and Assessment Strategies**Connection**

Teachers may

- Engage students in physics-related
 - decision making activities requiring them to develop reasoned arguments from science information sources and debate (e.g., debating whether construction of a high voltage power line should be permitted near schools); and
 - research inquiry and communicate their findings (e.g., investigate artificial satellite technology, investigate possible health effects from exposure to electromagnetic fields).

Students may

- Use a variety of sources to research a particular science-related problem. Using support information from those sources, defend a course of action to solve the problem.

Consolidation

Students may

- Participate in a debate on a science-related issue. Develop arguments based on information from a variety of sources and be prepared to defend your position based on this information.

Resources and Notes**Authorized**

Pearson Physics (SR)

- pp. 864-866

Pearson Physics 20 and 30 (TR)

- Assessment Rubric GR 11: Research Report

Section Three: Specific Curriculum Outcomes

Unit 1: Motion

Focus

In Physics 2204, students studied the kinematics and dynamics of one dimensional (1D) motion. In Physics 3204, treatment is extended to two dimensional (2D) motion. Students will analyze 2D motion in a horizontal plane and a vertical plane. Treatment will include relative motion, projectile motion, and application of the laws of conservation of momentum to collisions and explosions.

Hands on investigations of resultant displacement and projectile motion provide significant opportunities to address inquiry-related skill outcomes. The unit concludes with an STSE research inquiry activity into sports-related concussions and the design and function of safety equipment.

Outcomes Framework

GCO 1 (STSE): Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

- 26.0 distinguish between questions that can be answered by science and those that cannot, and between problems that can be solved by technology and those that cannot
- 27.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

- 3.0 design an experiment identifying and controlling major variables
- 4.0 formulate operational definitions of major variables
- 6.0 develop appropriate sampling procedures
- 7.0 estimate quantities
- 10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
- 13.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty
- 16.0 identify and correct practical problems in the way a technological device or system functions
- 18.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
- 19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

- 21.0 use vectors to represent displacement, velocity, acceleration, and force
- 22.0 identify the frame of reference for a given motion
- 23.0 analyze quantitatively two-dimensional motion in a horizontal plane and a vertical plane
- 24.0 analyze quantitatively the horizontal and vertical motion of a projectile
- 25.0 apply quantitatively the laws of conservation of momentum to two-dimensional collisions and explosions

GCO 4 (Attitudes): Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Students are encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- show a continuing and more informed curiosity and interest in science and science-related issues
- consider further studies and careers in science- and technology-related fields
- value processes for drawing conclusions
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

SCO Continuum

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

Science 1206	Physics 2204	Physics 3204
<ul style="list-style-type: none"> • describe quantitatively the relationship among motion variables • analyze mathematically the relationship among displacement, velocity, and time • analyze graphically the relationship among displacement, velocity, and time for uniform and non-uniform motion • distinguish between instantaneous and average velocity • describe quantitatively the relationship among velocity, time, and acceleration 	<ul style="list-style-type: none"> • use vectors to represent displacement, velocity, and acceleration • analyze quantitatively the horizontal or vertical motion of an object • identify the frame of reference for a given motion • use vectors to represent force and acceleration • apply Newton’s laws of motion to explain inertia, the relationship between force, mass, and acceleration, and the interaction of forces between two objects • apply quantitatively Newton’s laws of motion to impulse and momentum • apply quantitatively the laws of conservation of momentum to one dimensional collisions and explosions • determine which laws of conservation of energy or momentum are best used to solve particular real life situations involving elastic and inelastic collisions 	<ul style="list-style-type: none"> • use vectors to represent displacement, velocity, acceleration, and force • identify the frame of reference for a given motion • analyze quantitatively two-dimensional motion in a horizontal plane and a vertical plane • analyze quantitatively the horizontal and vertical motion of a projectile • apply quantitatively the laws of conservation of momentum to two-dimensional collisions and explosions

Suggested Unit Plan

September		October		November	December	January	February	March	April	May	June
Unit 1: Motion				Unit 2: Forces			Unit 3: Fields			Unit 4: Introduction to Quantum Physics	
Skills Integrated Throughout											

Vectors

Outcomes

Students will be expected to

21.0 use vectors to represent displacement, velocity, acceleration, and force [GCO 3]

7.0 estimate quantities [GCO 2]

13.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty [GCO 2]

18.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others [GCO 2]

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]

Focus for Learning

Prior to beginning Physics 3204, students should be proficient in unit conversion, scientific notation, and use of significant figures. A brief review may be warranted. Students are expected to apply rules for significant figures in all measurements and calculations (Appendix A), without the aid of a reference sheet.

In Physics 2204, students studied 1D displacement, velocity, acceleration, and force vectors. In Physics 3204, the focus is on the mathematical addition of vectors in 2D using the tip-to-tail method for vectors perpendicular to each other.

Remind students that all vectors will require a magnitude and direction. Students should be able to sketch vector quantities and perform calculations with directions expressed in a proper format. The expected format is

$$\vec{v} = 25.0 \text{ m/s } [30.0^\circ \text{ S of E}].$$

Students should carry out an investigation to determine resultant displacement using vectors. Quick Lab 2-2: Vector Walk (Pearson Physics, p. 79) provides a sample procedure. However, students should use compass directions (N, S, E, W) instead of angles based on polar coordinates (e.g., 270°).



Students should

- select a measuring device and carry out the procedure,
- calculate the resultant displacement and compare to measured values,
- calculate percent discrepancy,
- analyze the limits of their selected measuring device, and
- identify and explain sources of systematic and random error.

In addition to SCOs 7.0, 13.0, 18.0, and 19.0, providing choice in the selection of a measuring device (e.g., GPS, graduated rope, measuring tape, mobile device application, motion sensor, trundle wheel, ruler) may provide evidence to assess SCOs 5.0, 12.0, and 16.0. Refer to the *Integrated skills* unit for skill outcome elaboration.

Attitude

Encourage students to work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas. [GCO 4]

Sample Performance Indicators

1. Sketch the following vectors
 - $\vec{v} = 8.5 \text{ m/s } [35^\circ \text{ W of N}]$
 - $\vec{v} = 12 \text{ m/s } [58^\circ \text{ S of E}]$
2. Calculate the resultant displacement of a hiker who travels 8.0 km [E] and then 4.0 km [S]. Include a vector diagram.

Vectors

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Assess student understanding of 1D displacement, velocity, acceleration, and force vectors from Physics 2204, reteaching as deemed necessary.
- Facilitate a treasure hunt using a compass and a set of instructions to find successive clues.

Connection

Teachers may

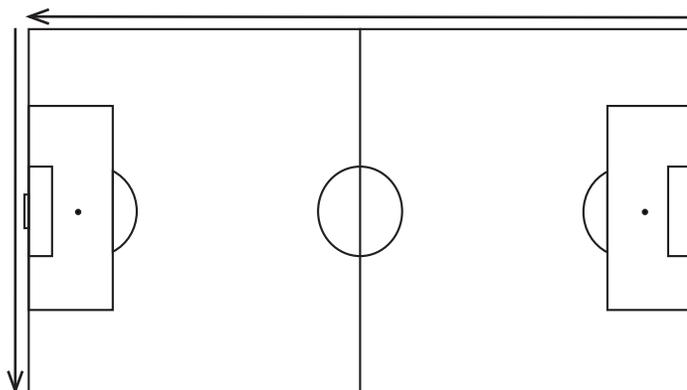
- Provide cards indicating a series of specific displacements measured in steps. Ask students to pace off each displacement in order and estimate their resultant displacement.
- Provide different groups different measuring instruments to measure the same displacements when investigating. Discuss the accuracy of the different instruments.

Students may

- Explore 2D vector addition using an online simulation.
- Discuss why [60° S of W] and [30° W of S] may be used to represent the same vector.

Consolidation

- Solve problems such as the following:
 - A cat travels 9.5 km [S], 2.0 km [N], and 5.0 km [W]. Draw a labelled vector diagram and determine the resultant displacement of the cat.
 - A soccer player runs the sidelines of a soccer pitch of dimensions 100.0 m by 65.0 m. What is the distance travelled and resultant displacement of the player?



Resources and Notes

Authorized

Appendices

- Appendix A

Pearson Physics Level 20
(Teacher Resource [TR])

- Unit I: Chapter 2 pp. 9-16

Pearson Physics (Student Resource [SR])

- pp. 76-90

Teaching and Learning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/teaching-and-learning-strategies.html
 - *Vector Displacement Walk*

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- 2D Vector addition (websites and videos)

Notes

The magnifying glass icon is used throughout the unit to indicate investigations.



Pearson Physics includes problems using non-right triangles which are beyond the scope of Physics 3204.

Relative Motion

Outcomes

Students will be expected to

22.0 identify the frame of reference for a given motion
[GCO 3]

23.0 analyze quantitatively two-dimensional motion in a horizontal plane and a vertical plane
[GCO 3]

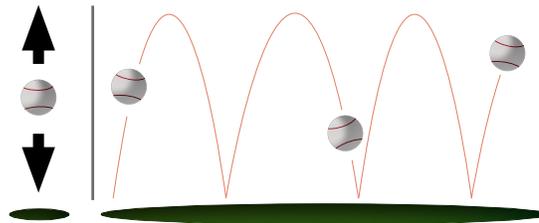
Focus for Learning

Frames of reference were previously addressed in Physics 2204. Students should define a frame of reference as a place from which motion is observed.

Given a situation, students should sketch the path of motion for a specified frame of reference.

Example

You are travelling on a bus at a constant speed while repeatedly tossing a baseball into the air. From your frame of reference (i.e., inside the bus), you see the motion as straight up and down. To an observer standing on the side of the road, however, they see the baseball tracing out arcs.



In Physics 2204, students analyzed 1D relative motion problems. In Physics 3204, students should quantitatively analyze 2D relative motion problems (limit to right triangles).

Treatment should include calculating

- relative velocity of an object using vector addition;
- required heading to reach an intended destination (See Example 2.6 *Pearson Physics*, pp. 94-95); and
- time to travel a given distance.

Ensure students are familiar with terms such as crosswind, air speed, and ground speed. In problems, describe winds and currents using the direction it is moving towards.

Attitude

Encourage students to value the role and contribution of science and technology in our understanding of phenomena. [GCO 4]

Continued

Relative Motion

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss real world situations where two velocity vectors might be interacting (e.g., bicycling with a crosswind, attempting to swim or kayak across a river).

Students may

- Discuss personal experiences encountering headwinds, tailwinds, or crosswinds.

Connection

Teachers may

- Present videos of airplanes landing in crosswinds.
- Demonstrate the effect of a crosswind or crosscurrent using a constant velocity cart and a treadmill running at low speed. Ask students, through trial and error, to determine the direction the cart must be aimed to finish directly across from the starting position. A mobile device may be used to capture a video record of the relative motion.

Students may

- Discuss why a flight from St. John's to Toronto takes longer than the return flight.
- Ride on a skate board while tossing and catching a ball. Ask a classmate to capture video of the event on a mobile device to record the observer's frame of reference.
- Explore relative motion using an online simulation (e.g., *oPhysics* - Relative Motion).

Consolidation

Students may

- Solve problems such as the following:
 - What is the resultant velocity of an airplane that travels through the air at 152 km/h [E] if there is a 40.0 km/h [S] crosswind? Include a vector diagram. What direction should the plane head if the pilot wants to end up directly East of the starting point?
 - A ship has a velocity of 12.0 km/h [W] with respect to the water. The current flows at 4.0 km/h [N]. Calculate the resultant velocity of the ship. Include a vector diagram.
 - The captain of a boat attempts to travel due East across a river that is 45.0 m wide. If the boat can travel at 5.0 m/s with respect to the water and the current flows at 3.0 m/s [S], how long does it take to travel directly across the river?

Resources and Notes

Authorized

Pearson Physics Level 20 (TR)

- Unit I: Chapter 2 pp. 16-20

Pearson Physics (SR)

- pp. 91-101

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- 2D Relative motion (websites and videos)

Relative Motion

Outcomes

Students will be expected to

22.0 identify the frame of reference for a given motion
[GCO 3]

23.0 analyze quantitatively two-dimensional motion in a horizontal plane and a vertical plane
[GCO 3]

Focus for Learning

Sample Performance Indicators

1. A cruise ship is travelling North. A passenger on the deck of the ship walks directly west with respect to the ship. Sketch a diagram of the velocity of the passenger with respect to the water.
2. Mark rode his personal water craft at a constant speed of 25 km/h [N] across a river with a current of 12 km/h [E]. What is Mark's velocity relative to the bank?
3. A small plane flies with a speed of 225 km/h relative to the air. The plane experiences a crosswind blowing 55 km/h [E].
 - What heading must the pilot use to fly due North?
 - What is the speed of the plane relative to the ground?
 - How long would it take the plane to reach an airport 575 km [N] of its starting point?

Relative Motion

Sample Teaching and Assessment Strategies**Resources and Notes****Authorized**

Pearson Physics Level 20 (TR)

- Unit I: Chapter 2 pp. 16-20

Pearson Physics (SR)

- pp. 91-101

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- 2D Relative motion (websites and videos)

Projectile Motion

Outcomes

Students will be expected to

- 24.0 analyze quantitatively the horizontal and vertical motion of a projectile [GCO 3]
- 3.0 design an experiment identifying and controlling major variables [GCO 2]
- 4.0 formulate operational definitions of major variables [GCO 2]
- 6.0 develop appropriate sampling procedures [GCO 2]
- 10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]
- 16.0 identify and correct practical problems in the way a technological device or system functions [GCO 2]

Focus for Learning

1D kinematics and calculations were addressed in Physics 2204. In Physics 3204 treatment is extended to 2D. For the purposes of this course, students should recognize that projectiles follow a parabolic path where the horizontal component of motion is uniform and the vertical component is free fall. Air resistance is assumed to be negligible.

As an introduction to projectile motion, students should devise and carry out two guided inquiry investigations to determine the effect of initial speed and launch height on the range of a projectile launched horizontally.



In small collaborative groups, students should

- design and construct a horizontal projectile launcher from a collection of possible materials (e.g., elastic bands, pipe insulation, wood ramp, Hot Wheels® track, curtain rods);
- devise a method to test the precision of the launcher, identifying and correcting problems;
- identify major variables and pose the questions to investigate;
- predict how projectile range is affected by the variables;
- operationally define variables and devise procedures to carry out controlled experiments;
- carry out their procedures, compiling and displaying data in appropriate formats;
- interpret trends in data, and infer linear and nonlinear relationships among variables;
- evaluate the reliability and adequacy of data and data collection methods;
- identify and explain sources of error; and
- draw conclusions.

In addition to SCOs 3.0, 4.0, 6.0, 10.0, and 16.0, these investigations provide opportunities to address and assess skill outcomes 5.0, 7.0, 11.0, 12.0, 13.0, 15.0, 18.0, and 19.0. Refer to the *Integrated Skills* unit for elaboration of skill outcomes.

After completing these investigations, students should use an online simulator to investigate the relationship between launch angle and range, and launch angle and time of flight. Students should determine the optimal launch angle for maximum range when launching and landing from the same height (i.e., vertical displacement is zero).

Attitude

Encourage students to value processes for drawing conclusions. [GCO 4]

Continued

Projectile Motion

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present sports videos depicting the balls travelling in a parabolic path (e.g., basketball, football, golf, volleyball).
- Present videos comparing the free fall of an object launched horizontally with one that is dropped. Note, the time for both is equivalent (See Figure 2.64, *Pearson Physics*, p. 104).

Connection

Teachers may

- Ask students at what angle they would project water from a garden hose to achieve maximum range. Then ask how this would change if there was a slight headwind.
- Relate the findings of investigations to designing of ramps and landing zones for nordic ski jumps, snowboard parks, and BMX tracks.

Students may

- Kick a football or soccer ball on a level field and investigate the effect of launch angle on range.
- Construct a ramp to launch a projectile at an angle above horizontal. Then, investigate to determine the launch angle and velocity required to hit a target.
- Explore projectile motion by manipulating variables in a projectile simulation (e.g., *PhET* - Projectile motion).
- Consider an airplane moving at a constant speed horizontally when a ball is released. Compare and describe the ball's path as seen from the plane and from the ground.

Consolidation

Students may

- Communicate the findings of their investigations in a lab report.
- Devise and carry out a procedure to determine the initial velocity of a kicked ball. Video analysis may be used to estimate the maximum height or launch angle.

Resources and Notes

Authorized

Pearson Physics Level 20 (TR)

- Unit I: Chapter 2 pp. 21-26

Pearson Physics (SR)

- pp. 102-112

Teaching and Learning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/teaching-and-learning-strategies.html
 - *Projectile Motion Guided Inquiry*

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Projectile motion (websites and videos)

Continued

Projectile Motion

Outcomes

Students will be expected to
24.0 analyze quantitatively the horizontal and vertical motion of a projectile [GCO 3]

Focus for Learning

Resolving force vectors into horizontal and vertical components was addressed in Physics 2204.

Students should sketch velocity and acceleration vectors for any point during a projectile's trajectory. They should resolve velocity vectors into components and solve problems where an object is launched

- horizontally and lands below the launch height;
- at an angle above the horizontal and lands at the launch height (i.e., zero vertical displacement);
- at an angle above the horizontal and lands above or below the launch height; and
- at an angle below the horizontal and lands below the launch height.

Students should solve for range, time of flight, velocity at any point (including initial and final velocity), and maximum height.

When solving projectile-related problems, encourage students to take care with the use of signs (i.e., if upwards is defined as positive then downwards must be negative) for vertical velocity component and vertical displacement.

Sample Performance Indicators

1. A toy car rolls off a lab bench ($h = 1.2$ m) at 3.0 m/s. How far would it travel horizontally before hitting the ground?
2. A soccer ball is kicked with a speed of 21.0 m/s at an angle of 37.0° above the horizontal. Calculate the time of flight and the maximum height.
3. A projectile is thrown from the top of a 30.0 m building. The initial projectile speed is 12.0 m/s and it is thrown upwards at an angle of 20.0° above the horizontal. Determine the projectile's range.
4. A cannon sitting on a 520 m high cliff, fires a cannon ball at 110 m/s, 65° below the horizontal. Calculate the impact velocity of the cannon ball.
5. A projectile is launched from the roof of a school ($h = 9.5$ m) and hits the ground 2.4 s later, after travelling 28 m horizontally. What was the initial velocity of the projectile?

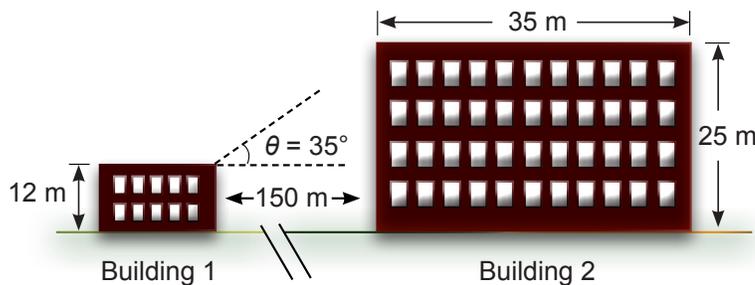
Projectile Motion

Sample Teaching and Assessment Strategies

Extension

Students may

- Solve problems such as the following:
 - Juliet throws a letter to Romeo who is on a balcony 3.0 m above the ground. If she throws it with a velocity of 6.4 m/s [45° above the horizontal] can the letter reach him?
 - A fish at the surface of a pond shoots a stream of water at a bug 0.26 m above the water with a range of 3.0 m. If the initial velocity of the water is 6.0 m/s at 30.0° above the horizontal, does the water hit the bug?
 - A projectile launcher launches a snowball at a velocity of 45 m/s [35° above the horizontal] from the top of building 1. Does the snowball land on top of building 2? Support your answer with calculations.



- A biker hits a jump on his motorbike at 27.0 m/s 35° above the horizontal. The jump is 120.0 m above the ground. The biker lands on a platform of unknown height 145.0 m away from the cliff. How high is the platform that the biker lands on?
- Three projectiles are launched at different angles, 25°, 43°, and 75° respectively, but with the same initial speed. All the projectiles are launched from and land on the ground. A student argues that the projectile launched at 43° will have the longest flight time because it has the largest range. Is the student correct? Explain.

Resources and Notes

Authorized

- Pearson Physics Level 20* (TR)
- Unit I: Chapter 2 pp. 21-26
- Pearson Physics* (SR)
- pp. 102-112

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Projectile motion (websites and videos)

Momentum and Collisions

Outcomes

Students will be expected to

25.0 apply quantitatively the laws of conservation of momentum to two-dimensional collisions and explosions
[GCO 3]

Focus for Learning

In Physics 2204, students studied momentum in 1D. In Physics 3204, momentum conservation is extended to 2D collisions.

Students should solve problems involving 2D collisions and explosions where momentum is conserved and masses are given. Problems will require the use of components:

$$\sum \vec{p}_x \text{ (before)} = \sum \vec{p}_x \text{ (after)}$$

$$\sum \vec{p}_y \text{ (before)} = \sum \vec{p}_y \text{ (after)}$$

Graphic organizers may be used to organize information when solving problems.

<u>Before Collision</u>				<u>After Collision</u>		
	Object 1	Object 2		Object 1	Object 2	
\vec{p}_x	$m_1 \vec{v}_{1x}$	$m_2 \vec{v}_{2x}$	=	\vec{p}_x	$m_1 \vec{v}'_{1x}$	$m_2 \vec{v}'_{2x}$
\vec{p}_y	$m_1 \vec{v}_{1y}$	$m_2 \vec{v}_{2y}$		\vec{p}_y	$m_1 \vec{v}'_{1y}$	$m_2 \vec{v}'_{2y}$

Limit 2D momentum problems to:

- A moving object colliding with a stationary object (both scatter). Give at least one velocity with angle measurement after the collision and ask students to determine the final velocity of the other particle or the initial velocity of the moving particle.
- Two moving objects colliding at 90° .
 - For elastic (both scatter) collisions, give at least one velocity with angle measurement after the collision and ask students to determine the final velocity of the other particle or the initial velocity of one moving particle.
 - For inelastic (stick together) collisions, ask students to determine the final velocity of the particle after the collision or the initial velocity of one moving particle.
- An explosion where one object separates into three separate pieces; one piece moving horizontally, the second piece moving vertically, and the third piece moving at some angle. Ask students to determine
 - the velocity (magnitude and direction) of the third piece after the explosion, given the velocities of the other two pieces; and
 - the velocities of the first and second pieces, given the velocity of the third piece moving at an angle.

Continued

Momentum and Collisions

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Demonstrate 2D collisions using manipulatives (e.g., children's pool table, air hockey, two balls).
- Present videos showing elastic and inelastic 2D collisions.

Students may

- Share personal examples where 2D collisions occur (e.g., playing pool, curling, car accidents, checking in hockey).
- Investigate 2D collisions using video analysis.
- Discuss how investigators might use 2D collision analysis to reconstruct vehicle accidents at an intersection.

Consolidation

Students may

- Carry out Inquiry Lab 9-6: Analyzing Collisions in Two Dimensions (*Pearson Physics*, pp. 488-89).
- Investigate 2D collisions using an online simulation (e.g., *PhET - Collisions Lab* [advanced]).
- Solve problems such as the following:
 - A 2.0×10^3 kg car travelling at 20.0 m/s [N] is struck at an intersection by a 2500 kg pickup truck travelling at 14.0 m/s [W]. If the vehicles stick together upon impact, what will be the velocity of the car-truck combination immediately after the collision?
 - A 0.400 kg grenade is stationary when it explodes into three fragments. One 0.237 kg fragment (A) goes off at 19.7 m/s [35° S of E]. A second fragment (B), of mass 0.066 kg, travels due North, while a third fragment (C), of mass 0.097 kg travels due West. Determine the velocity of the second and third fragments after the explosion.
 - An 86.4 kg defenseman skating at 2.46 m/s [S] collides with an 84 kg centreman skating directly West. The players fall in a tangle and slide at 1.57 m/s [52° S of W]. What was the initial velocity of the centreman?

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit V: Chapter 9 pp. 33-42

Pearson Physics (SR)

- pp. 487-495

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- 2D collisions (websites and videos)

Note

Pearson Physics uses different notation for quantities involved in 2D collisions.

Continued

Momentum and Collisions

Outcomes

Students will be expected to

*25.0 apply quantitatively the laws of conservation of momentum to two-dimensional collisions and explosions
[GCO 3]*

Focus for Learning

Although kinetic energy is also conserved in 2D elastic collisions, calculations of kinetic energy are not required in Physics 3204.

Sample Performance Indicators

1. Two identical curling stones ($m = 19.5 \text{ kg}$) collide. Stone 1 is initially at rest and travels 3.2 m/s [$30.0^\circ \text{ W of N}$] after the collision. Stone 2 was travelling 5.0 m/s [N] before the collision. What is the velocity of stone 2 after the collision?
2. Two billiard balls with identical mass collide ($m = 0.160 \text{ kg}$). Prior to the collision, ball 1 was travelling 2.20 m/s [S] and ball 2 was travelling 3.10 m/s [W]. After the collision, ball 1 was travelling 2.56 m/s [$14.0^\circ \text{ N of W}$]. Determine the velocity of ball 2 after the collision.
3. A 1200.0 kg car (A) strikes a stationary 1350.0 kg car (B) off centre from behind. Accident analysis showed that after the collision, car B moved at 8.30 m/s [35° N of E], and car A moved 12.8 m/s [53° N of W]. What was the velocity of the car just before collision?
4. Two bumper cars collide and stick together. Car 1 ($m = 150 \text{ kg}$) is travelling 3.5 m/s [N] when it strikes car 2 ($m = 95 \text{ kg}$), travelling 2.5 m/s [E]. What is their combined velocity after colliding?
5. A 0.058 kg firecracker that is at rest explodes into three fragments. A 0.018 kg fragment moves at 2.40 m/s [N] while a 0.021 kg fragment moves at 1.60 m/s [E]. What will be the velocity of the third fragment?

Momentum and Collisions

Sample Teaching and Assessment Strategies

Extension

Students may

- Solve problems such as the following:
 - The police are investigating an accident. They have determined that the mass of car A is 2275 kg and was traveling North before the collision, while car B has a mass of 1525 kg and was traveling East just before the collision. Accident analysis has determined that the cars, when they were locked together, had a velocity of 31 km/h [43° N of E]. If the speed limit was 35 km/h on both streets, should one or both cars be ticketed for speeding?

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit V: Chapter 9 pp. 33-42

Pearson Physics (SR)

- pp. 487-495

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- 2D collision resources (websites and videos)

Momentum and Collisions STSE

Outcomes

Students will be expected to

26.0 distinguish between questions that can be answered by science and those that cannot, and between problems that can be solved by technology and those that cannot [GCO 1]

27.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]

Focus for Learning

Stemming from treatment of momentum and 2D collisions, students should engage in research inquiry to explore the issue of concussions in sports (e.g., football, hockey, soccer).

Exploration of the issue should include discussion regarding the limits of science and technology. Students should distinguish between questions/problems that can be solved by science and technology (e.g., How can hockey helmets be redesigned to prevent concussions?) and those that cannot (e.g., Should fighting be banned in hockey?).

Treatment may be extended to include an engineering design challenge where student collaboratively design and test a helmet to reduce concussions.

At the conclusion of the unit, students should analyze the knowledge and skills they've acquired related to vectors, 2D relative and projectile motion, and momentum and collisions, to identify areas of further study. Their analysis should lead to exploration of careers where this knowledge and skills would be required.

This outcome should be readdressed at the conclusion of each subsequent unit.

Attitudes

Encourage students to

- show a continuing and more informed curiosity and interest in science and science-related issues, and
- consider further studies and careers in science- and technology-related fields. [GCO 4]

Momentum and Collisions STSE

Sample Teaching and Assessment Strategies

It is recommended that students create and maintain a personal STSE portfolio. As the course progresses, they should add physics-related articles to their portfolio, from traditional and social media, and tag each article with relevant STSE outcomes (i.e., GCO 1).

Connection

Students may

- Explore STEM careers using online resources.

Consolidation

Students may

- Explore articles and videos sourced online related to concussions in sports and the importance of helmets to reduce injury.
- Research concussion-related symptoms.
- Discuss how to prevent injuries in sports.
- Complete an online concussion awareness course.
- Analyze the design of hockey or football helmets developed to reduce head injuries.

Resources and Notes

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Concussion resources (websites and videos)
- STEM careers (websites and videos)

Section Three: Specific Curriculum Outcomes

Unit 2: Forces

Focus

An understanding of forces and motion affects our lives whether we are driving a car or riding a roller coaster at an amusement park. Newton's laws of motion were revolutionary because they explained the behaviour of moving objects and systems on Earth and in our universe. In this unit, students will investigate uniform circular motion, forces on an inclined plane, and systems involving static equilibrium and torques.

Hands on investigations provide opportunities to address inquiry-related skill outcomes.

Outcomes Framework

GCO 1 (STSE): Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

27.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

- 2.0 design an experiment and identify specific variables
- 5.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making
- 7.0 estimate quantities
- 10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
- 11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
- 13.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty
- 15.0 explain how data support or refute the hypothesis or prediction
- 17.0 identify and evaluate potential applications of findings
- 18.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
- 19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

28.0 describe uniform circular motion, using algebraic and vector analysis
29.0 explain quantitatively circular motion using Newton's laws
30.0 analyze quantitatively two-dimensional motion in a parallel and perpendicular plane
31.0 analyze quantitatively two-dimensional systems involving mass, static equilibrium, and torques

GCO 4 (Attitudes): Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Students are encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- show a continuing and more informed curiosity and interest in science and science related issues
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

SCO Continuum

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

Science 1206	Physics 2204	Physics 3204
<ul style="list-style-type: none"> • describe quantitatively the relationship among motion variables • analyze mathematically the relationship among displacement, velocity, and time • analyze graphically the relationship among displacement, velocity, and time for uniform and non-uniform motion • distinguish between instantaneous and average velocity • describe quantitatively the relationship among velocity, time, and acceleration 	<ul style="list-style-type: none"> • use vectors to represent displacement, velocity, force, and acceleration • analyze quantitatively the horizontal or vertical motion of an object • apply Newton's laws of motion to explain inertia, the relationship between force, mass, and acceleration, and the interaction of forces between two objects • apply quantitatively Newton's laws of motion to impulse and momentum 	<ul style="list-style-type: none"> • describe uniform circular motion, using algebraic and vector analysis • explain quantitatively circular motion using Newton's laws • analyze quantitatively two-dimensional motion in a parallel and perpendicular plane • analyze quantitatively two-dimensional systems involving mass, static equilibrium, and torques

Suggested Unit Plan

September	October	November	December	January	February	March	April	May	June
Unit 1: Motion		Unit 2: Forces			Unit 3: Fields			Unit 4: Introduction to Quantum Physics	
Skills Integrated Throughout									

Uniform Circular Motion

Outcomes

Students will be expected to

28.0 describe uniform circular motion, using algebraic and vector analysis
[GCO 3]

29.0 explain quantitatively circular motion using Newton's laws
[GCO 3]

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
[GCO 2]

15.0 explain how data support or refute the hypothesis or prediction
[GCO 2]

Focus for Learning

In Physics 2204, students investigated linear motion whereby a force was applied with or against the direction of motion causing linear acceleration. While students have previously studied uniform motion, this is their first introduction to uniform circular motion (UCM).

Students should define UCM. Emphasize that an object can be moving at a constant speed, but still accelerating when there is a change in direction, as in UCM. Draw on students' personal experiences with UCM (e.g., roller coaster in a loop, bicycle tires, cars going around a turn) to differentiate between horizontal and vertical circular motion.

Students should solve UCM problems using $v = \frac{2\pi r}{T}$, $a_c = \frac{v^2}{r}$,

and their combination. Teachers may show how the formula for speed is derived.

The relationship between period and frequency, $T = \frac{1}{f}$, was

addressed in Physics 2204. Students should solve UCM problems using either quantity.

Students are not expected to derive the equation for centripetal acceleration. They should recognize, however, that velocity and acceleration are perpendicular to each other, and that velocity is tangential to the circle at all points.

Relate Newton's first law to UCM, demonstrating how an object moving in a circular path, when released, travels tangentially in a straight line. Therefore a force is required to keep the object moving in a circular path. Relate Newton's second law to UCM, demonstrating

how $\vec{F}_{\text{net}} = m\vec{a}$ becomes $\vec{F}_c = m\vec{a}_c$, then $\vec{F}_c = \frac{mv^2}{r}$.

Students should carry out two inquiry investigations to determine the relationships between speed and radius, and speed and centripetal force (e.g., *Pearson Physics*, pp. 245-246, 257-258).



Students should

- state hypotheses relating speed to radius and centripetal force;
- carry out procedures, compiling their data in tables;
- construct graphs to analyze and interpret data and to determine relationships; and
- explain how the data supports or refutes their hypothesis.

Skill outcomes 7.0, 13.0, 16.0, 18.0 and 19.0 may also be assessed. Refer to the *Integrated Skills* unit for elaboration.

Continued

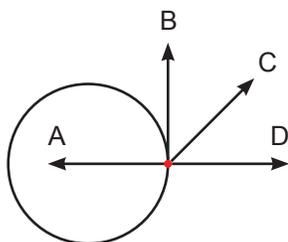
Uniform Circular Motion

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present the following diagram. Ask students to predict the path the ball will take when the string breaks.



Confirm or refute students' predictions with a safe demonstration.

- Ask students to repeatedly tap a moving tennis ball on the floor with a metre stick to create "circular" motion. They should discover that they need to tap the outside of the ball to provide the centripetal force needed to cause the ball to move in a circle.

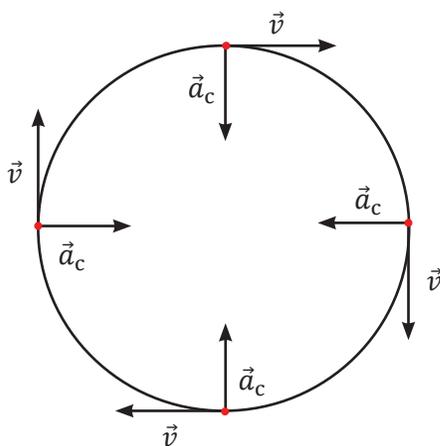
Students may

- Place a coin inside a balloon and inflate it. Manipulate the balloon to first move the coin in a horizontal circle, then a vertical circle. Discuss how the centripetal force differs for each scenario.

Connection

Teachers may

- Present this diagram to illustrate the velocity and acceleration vectors on different points on the circular path. Note, velocity is tangent to the circular and acceleration is perpendicular to velocity.



Continued

Resources and Notes

Authorized

Pearson Physics Level 20
(Teacher Resource [TR])

- Unit III: Chapter 5 pp. 5-22

Pearson Physics (Student Resource [SR])

- pp. 240-268

Teaching and Learning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/teaching-and-learning-strategies.html
 - *Uniform Centripetal Motion Lab*

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html



- Uniform circular motion (websites and videos)

Notes

The magnifying glass icon is used throughout the unit to indicate investigations.

Uniform Circular Motion

Outcomes

Students will be expected to

28.0 describe uniform circular motion, using algebraic and vector analysis
[GCO 3]

29.0 explain quantitatively circular motion using Newton's laws
[GCO 3]

Focus for Learning

Students should apply Newton's second law to solve UCM problems.

Encourage students to begin solutions to problems from $\vec{F}_{\text{net}} = m\vec{a}$. Note, including centripetal force in FBDs is a common student error.

For horizontal and vertical circular motion problems, students should

- identify the specific force(s) causing centripetal motion;
- draw a free body diagram (FBD);
- develop equations based on analysis of the forces; and
- solve for speed, tension, radius, force of friction, coefficient of static friction, maximum and minimum speed, maximum and minimum tension, and normal force.

For vertical circles, treatment should only address motion at the top or bottom of the circle (i.e., no points in between).

The notation \vec{T} or \vec{F}_T may be used for tension.

Attitudes

Encourage students to

- show a continuing and more informed curiosity and interest in science and science related issues, and
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas. [GCO 4]

Sample Performance Indicators

1. An object undergoes UCM at a speed of 6.20 m/s ($r = 3.85$ m). How long does one revolution take?
2. Wheels on a moving bicycle make two rotations in 0.18 s. If the tire radius is 0.37 m, how fast is the bicycle travelling? What is the magnitude of the wheels' centripetal acceleration?
3. You are swinging a bucket of water in a vertical circle with a radius of 0.95 m. What minimum speed must be reached at the top of the vertical circle to prevent the water from spilling out?
4. A car of mass 1.50×10^3 kg travelling at 18 m/s, crests a hill having a radius of curvature of 50.0 m.
 - Calculate the normal force on the car at the top of the hill.
 - Calculate the maximum speed that will allow the car to stay on the road at the top of the hill.

Uniform Circular Motion

Sample Teaching and Assessment Strategies

Connection (continued)

Teachers may

- Present videos of individuals experiencing weightlessness and G-LOC.

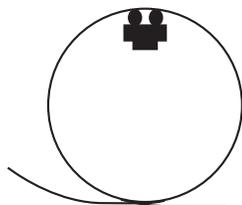
Students may

- Place an object in a small bucket attached to a string. Measure the mass and string length (i.e., circle radius) and determine how fast the bucket must revolve vertically to prevent the object from falling out at the top of the path.
- Use an online simulator (e.g., *Physics classroom* - Uniform Circular Motion Interactive) to explore the effects of speed, radius, and object mass on acceleration and net force in UCM.

Consolidation

Students may

- Solve problems such as the following:
 - A boy twirls a 155 g ball on a 1.65 m string in a horizontal circle. The string will break if the tension reaches 208 N. What is the maximum speed at which the ball can move without breaking the string?
 - A superhero ($m = 110$ kg) swings vertically on a rope and grappling hook at a speed of 7.11 m/s in a circular path ($r = 9.5$ m). The maximum tension the rope can withstand is 1650 N. Will the rope break?
 - The diagram shows a roller coaster going through a circular loop of radius 18.0 m. What is the minimum speed needed at the top of the loop to prevent the passengers from falling out?



Extension

Students may

- Solve problems such as the following:
 - A 1.50 kg cat jumps onto a merry-go-round just as it is put in motion. The cat is 2.50 m from the centre of the merry-go-round and completes 5 full revolutions every 40.0 s. What is the coefficient of friction?

Resources and Notes

Authorized

Pearson Physics Level 20 (TR)

- Unit III: Chapter 5 pp. 5-22

Pearson Physics (SR)

- pp. 240-268

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Uniform circular motion (websites and videos)

Continued

Uniform Circular Motion

Outcomes

Students will be expected to

*28.0 describe uniform circular motion, using algebraic and vector analysis
[GCO 3]*

*29.0 explain quantitatively circular motion using Newton's laws
[GCO 3]*

Focus for Learning

Uniform Circular Motion

Sample Teaching and Assessment Strategies

Extension (continued)

Students may

- Solve problems such as the following:
 - A space station has a radius 175 m. It rotates to simulate 0.65 *g*. How many rotations per minute does the space station make?
 - A person, with a mass of 65.0 kg, on a carnival ride stands inside a large drum of radius 5.0 m that begins to rotate. When a safe speed is reached, the floor of the drum falls away and the rider is left “stuck” to the wall. If the coefficient of friction is 0.54, What is the minimum speed at which the drum can turn so that the person does not fall?
 - A roller coaster cart passes the point at the very top on the inside of a circular loop, which has a radius of 9.00 m. If the normal force is equal to one half the weight of the cart, what is the speed of the roller coaster at this point?

Resources and Notes

Authorized

Pearson Physics Level 20 (TR)

- Unit III: Chapter 5 pp. 5-22

Pearson Physics (SR)

- pp. 240-268

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Uniform circular motion (websites and videos)

Forces on an Inclined Plane

Outcomes

Students will be expected to

30.0 analyze quantitatively two-dimensional motion in a parallel and perpendicular plane
[GCO 3]

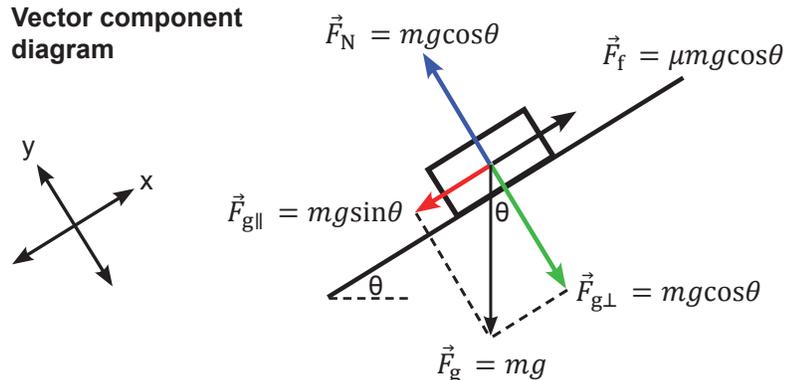
Focus for Learning

In Physics 2204, students solved problems involving Newton's laws on a horizontal surface. In Physics 3204, student learning will be extended to inclined planes.

Students should

- rotate the coordinate system to match the inclined plane and refer to these new directions as parallel and perpendicular to the incline;
- draw an FBD for the object on the inclined plane; and
- identify that the weight of an object on an inclined plane is comprised of two components, the parallel component ($\vec{F}_{g\parallel}$) and the perpendicular component ($\vec{F}_{g\perp}$).

Vector component diagram



Equating \vec{F}_N and \vec{F}_g is a common student error.

Students should solve problems involving an object at rest or sliding up or down an inclined plane, with or without friction, and solve for

- friction,
- coefficient of friction,
- tension (in a string holding an object stationary on the inclined plane),
- acceleration,
- mass, and
- angle of incline.

Continued

Forces on an Inclined Plane

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss why larger angle inclines are used to gain a greater acceleration down a slope when skateboarding or snowboarding. Illustrate with video clips of increasing slopes resulting in increasing applied force, hence increasing acceleration.
- Relate incline angles to loading snowmobiles into a pickup truck.

Connection

Teachers may

- Using a T-square, demonstrate how a coordinate plane is rotated to match an incline. Alternatively, a digital image can be rotated.

Consolidation

Students may

- Predict if an object will slide down an incline given parameters (e.g., mass, coefficient of friction, angle of incline). Test predictions using an online simulator (e.g., *PhET* - The Ramp).
- Solve problems such as the following:
 - A sled (14 kg) is on a hill that is inclined 25° to the horizontal. The hill is very icy (negligible friction) and the sled is held at rest by a rope attached to a post. The rope is parallel to the hill. Calculate the magnitude of the tension in the rope.
 - A crate is placed on an inclined board and is hinged so that the angle is adjustable. The coefficient of static friction between the crate and the board is 0.30. Determine the angle at which the crate just begins to slip.
 - In a physics experiment, a 1.3 kg dynamics cart is placed on a frictionless ramp inclined at 25° to the horizontal. The cart is pulled up the ramp at a constant speed by applying a force parallel to the ramp. What is the applied force?

Extension

Students may

- Solve problems such as the following:
 - A sled at the top of a frictionless hill makes an angle of 18° with the horizontal. The sled travels 81 m to reach the bottom of the hill. Calculate the speed of the sled as it reaches the bottom of the hill.
 - A skier starts from rest and begins descending a 30.0° slope. The coefficient of kinetic friction is 0.10. What is the acceleration of the skier? How far down the slope will the skier travel in 10.0 s?

Resources and Notes

Authorized

Pearson Physics Level 20 (TR)

- Unit II: Chapter 3 pp. 39-50

Pearson Physics (SR)

- pp. 173-190

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Forces on inclines (websites and videos)

Forces on an Inclined Plane

Outcomes

Students will be expected to

30.0 analyze quantitatively two-dimensional motion in a parallel and perpendicular plane

[GCO 3]

2.0 design an experiment and identify specific variables

[GCO 2]

5.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making

[GCO 2]

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

[GCO 2]

18.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others

[GCO 2]

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

[GCO 2]

Focus for Learning

Students should design investigations to determine the coefficients of static and kinetic friction for an inclined plane. For static friction they should construct an incline and determine the angle at which the object starts to slide. For kinetic friction, students should

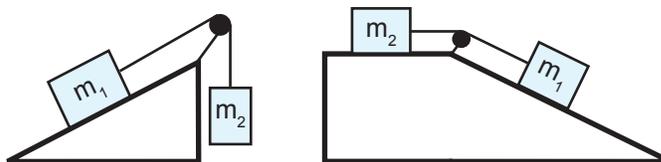
- set the incline at an angle that causes the object to slide down without a push;
- determine how they will measure acceleration (e.g., ticker tape, d-t data, motion sensor, slow motion camera and timer), select appropriate instruments, and develop appropriate sampling procedures and data treatments;
- devise and carry out their procedure, adapting and extending where required;
- compile, organize, and display their data in appropriate formats, and perform calculations; and
- draw conclusions, identifying and explaining sources of error and uncertainty.

Student findings may be communicated, using appropriate modes of representation, in a lab report.

In addition to the outcomes listed, teachers may assess skill outcomes 4.0, 6.0, 7.0, 13.0, and 16.0. Refer to the *Integrated Skills* unit for elaboration. The investigation may be extended to compare inclines made from different materials.

Students should solve problems involving strings and pulleys on inclined planes with and without friction. Limit problems to the following setups with

- one incline,
- two masses and one pulley, and
- friction on one or both surfaces.



Students should calculate acceleration of the blocks and tension in the string. The direction of motion should be provided.



Continued

Forces on an Inclined Plane

Sample Teaching and Assessment Strategies

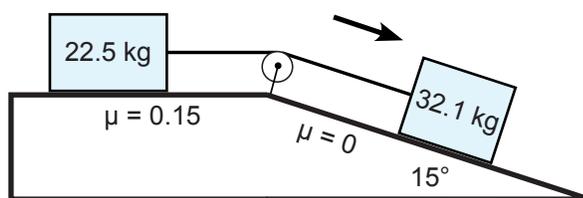
Connection

Teachers may

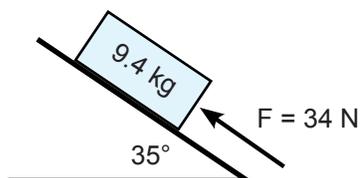
- Present Myth Busters *Banana Slip* episode to illustrate static friction on inclines.
- Discuss how the application of hanging objects (forces of gravity) or objects on inclines (a component of the gravitational force) may be used to provide an applied force to move objects that otherwise may not be moved by direct forces.

Students may

- Solve problems such as the following:
 - Two masses are connected by a string as shown in the picture below. Calculate the tension in the string.



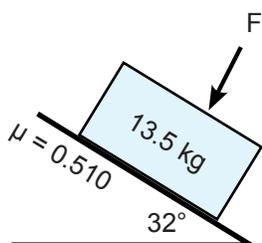
- A 9.4 kg mass is being held at rest by a force of 34 N on a 35° incline plane. Calculate the coefficient of static friction between the mass and the incline.



Extension

Students may

- Solve problems such as the following:
 - An external force, F , is applied to the top of a 13.5 kg mass to keep it from sliding down an inclined plane. The inclined plane has a coefficient of friction of 0.510 and is angled at 32.0°. What is the minimum value of F that keeps the mass at rest on the incline?



Continued

Resources and Notes

Authorized

Pearson Physics Level 20 (TR)

- Unit II: Chapter 3 pp. 39-50

Pearson Physics (SR)

- pp. 173-190

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Inclines (websites and videos)

Forces on an Inclined Plane

Outcomes

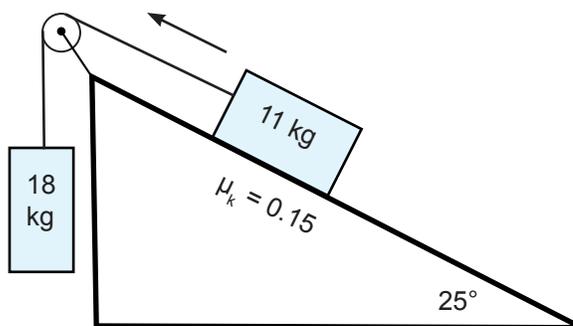
Students will be expected to

30.0 analyze quantitatively two-dimensional motion in a parallel and perpendicular plane
[GCO 3]

Focus for Learning

Sample Performance Indicators

1. What is the acceleration of a 12.0 kg mass sliding down an incline at an angle of 25° if $\mu_k = 0.15$?
2. A 70.0 kg skier accelerates at 2.0 m/s^2 while descending from rest down a 17° slope. What is the force of friction between the skis and the sloped surface?
3. Two objects of masses 11 kg and 18 kg are connected by a light string that passes over a frictionless pulley as shown.
 - Calculate the magnitude of the acceleration of the system.
 - Calculate the tension in the string.



4. If a 4.00 kg box slides down a frictionless incline with an acceleration of 3.90 m/s^2 , what is the angle of the incline?

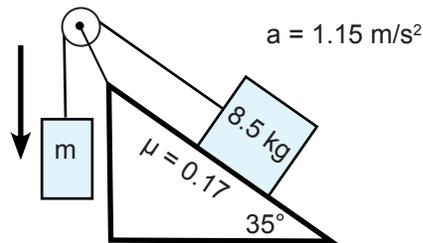
Forces on an Inclined Plane

Sample Teaching and Assessment Strategies

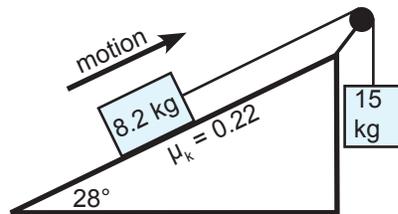
Extension (continued)

Students may

- Solve problems such as the following:
 - Two masses are connected over a pulley by a string. Determine the value of the missing mass, m .



- Given the following diagram, and that the maximum tension that the rope can withstand is 150.0N , determine whether the string will break.



- A rock slides from rest down a 15.5 m long ramp into a pool of water. If the ramp's incline is 35° above the horizontal and the coefficient of kinetic friction between the rock and the ramp is 0.25 , how long does it take the rock to hit the water?

Resources and Notes

Authorized

- Pearson Physics Level 20 (TR)*
- Unit II: Chapter 3 pp. 39-50
- Pearson Physics (SR)*
- pp. 173-190

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Inclines (websites and videos)

Static Equilibrium

Outcomes

Students will be expected to

31.0 analyze quantitatively two-dimensional systems involving mass, static equilibrium, and torques [GCO 3]

Focus for Learning

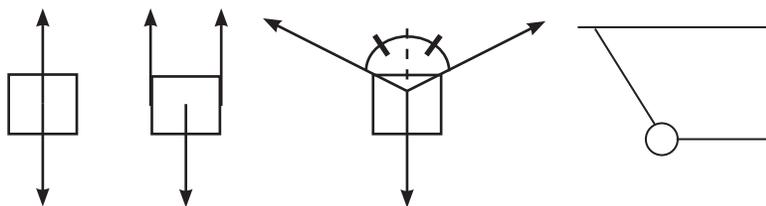
In Physics 2204, students calculated net forces and tension in 1D situations. In Physics 3204, this will be extended to 2D.

Students should

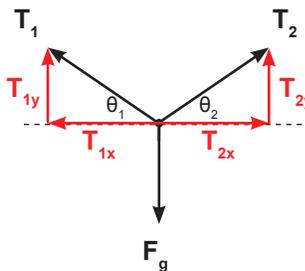
- recognize translational equilibrium (i.e., $\vec{F}_{\text{net}} = 0$) and rotational equilibrium (i.e., $\vec{\tau}_{\text{net}} = 0$) as the two conditions required to maintain static equilibrium; and
- solve static equilibrium problems (i.e., translational and rotational).

Translational equilibrium

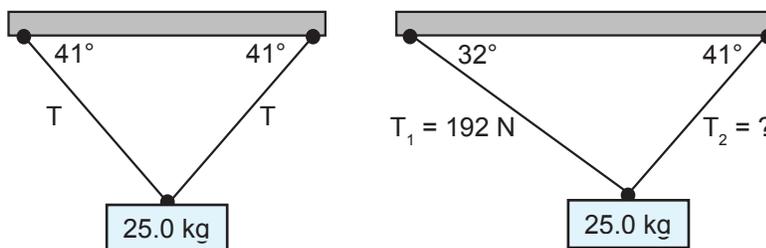
Treatment should progress through problems with increasing complexity that mirror those outlined below.



Emphasis should be placed on drawing properly labelled FBDs. Note, while force components are needed to solve problems, they are not part of the FBD.



Students should solve for tension, angle, weight, and mass of objects in translational equilibrium problems. Examples should include the following.



For unequal angle problems, provide at least one tension.

Continued

Static Equilibrium

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss with students the importance of objects maintaining static equilibrium, such as in the design of bridges, hanging signs, hydro wires, or any type of support structures.
- Discuss situations involving rotational motion and static equilibrium including see-saws, levers, hanging masses, screw drivers, opening doors, opening bottles, and movement of limbs.

Connection

Teachers may

- Place a heavy mass in the middle of a string and ask a pair of students to try to pull the ends of the string to make it more horizontal. They should note the vertical component of tension counteracting the weight of the mass and the increase in tensions as the string becomes more horizontal. Make the connection to ice build up on power lines.

Students may

- Hang various masses from two equal angles with force meters or spring scales to show that the tensions are equivalent. Then, hang them from different angles to explore changes in tension. Students could estimate tensions in each string before reading the values.

Resources and Notes

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Static equilibrium (websites and videos)

Note

Static equilibrium is not covered in the *Pearson Physics* student resource.

Static Equilibrium

Outcomes

Students will be expected to

31.0 analyze quantitatively two-dimensional systems involving mass, static equilibrium, and torques [GCO 3]

7.0 estimate quantities [GCO 2]

13.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty [GCO 2]

17.0 identify and evaluate potential applications of findings [GCO 2]

27.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]

Focus for Learning

Rotational equilibrium

Students should define the centre of mass for uniform objects. Note, treatment should be limited to uniform objects.

They should define torque as $\vec{\tau} = r\vec{F}_{\perp}$ or $\vec{\tau} = r\vec{F}\sin\theta$, where θ is the angle between the force and the object to which it is applied, and r is the distance from the pivot point to where the force is applied.

Additionally, students should provide examples of and calculate torque. Situations should include forces applied perpendicularly or at an angle.

Using a metre stick, fulcrum, and hanging masses, students should follow procedures to determine the balance point between masses hung on opposite ends of the metre stick. They should record mass and distance from pivot, for each side of the metre stick, and calculate the weight and torque.

Note, torque calculations will likely be unequal due to the weight of the metre stick. Discuss this discrepancy with students. Consider extending the activity to calculate the experimental weight and mass of the metre stick and compare with its actual measured mass.

Refer to the *Integrated Skills* unit for elaboration of SCOs 7.0, 13.0, and 17.0.

Students should solve static equilibrium problems related to

- balanced see-saws;
- horizontal beams or bridges;
- cantilevers;
- horizontal struts with one cable at an angle; and
- ladders (Limit to problems with one person on the ladder. Assume a frictionless wall. Calculating ground force is not an expectation.)

Students should draw FBDs illustrating all forces. The direction system can be simplified by letting $\tau_{\text{CW}} = \tau_{\text{CCW}}$, which is the same as $\vec{\tau}_{\text{net}} = 0$.

Students should reflect on their study of UCM, 2D motion in parallel and perpendicular planes, and static equilibrium, to identify areas of further study and related careers.

Attitude

Encourage students to value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not. [GCO 4]



Continued

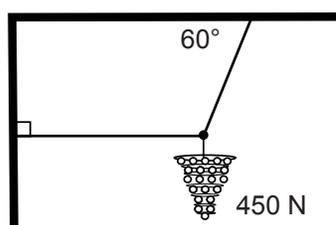
Static Equilibrium

Sample Teaching and Assessment Strategies

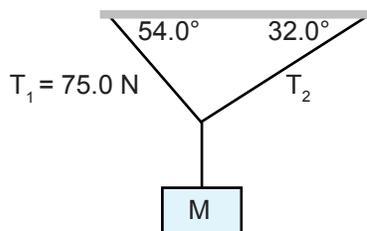
Consolidation

Students may

- Solve problems such as the following:
 - A 450 N chandelier is supported by three cables as shown in the diagram. What is the tension in the horizontal cable?



- A sign of mass M hangs from two cables as shown below. Calculate the mass of the sign if it is in static equilibrium.



- Investigate the design of bridges to show how they can support more weight over longer distances.
- Research the application of torque to movement of limbs and how it relates to careers such as kinesiology and physiotherapy.
- Use an interactive online simulation (e.g., *PhET* - Balancing Act) to explore static equilibrium and torque.
- Discuss how torques are used in automobile manufacturing. Every bolt has a specific maximum/minimum torque that must be applied.
- Research wheel lug nut torque specifications for different types of vehicles and rims. Lug nut torques generally range from 90-110 N·m. Exceeding the specified torque may break the bolts, insufficient torque may result in the rims coming off the vehicle. Students may be familiar with torques measured using foot pounds. They may extend research to determine lug nut torque specification in foot pounds.

Resources and Notes

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Static equilibrium (websites and videos)

Note

Static equilibrium is not covered in the *Pearson Physics* student resource.

Continued

Static Equilibrium

Outcomes

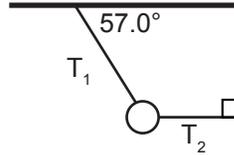
Students will be expected to

31.0 analyze quantitatively two-dimensional systems involving mass, static equilibrium, and torques [GCO 3]

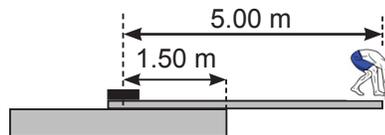
Focus for Learning

Sample Performance Indicators

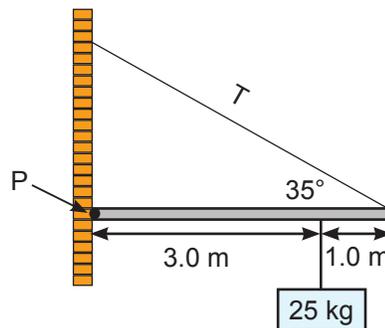
1. What is the tension T_1 , if $T_2 = 255 \text{ N}$?



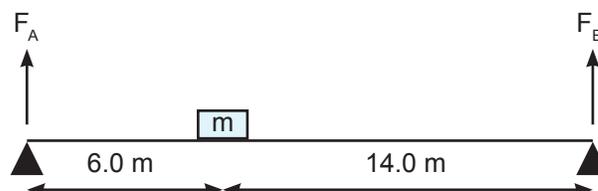
2. A see-saw pivots at its centre. A 32 kg mass is placed 1.5 m to the left of the pivot. How far to the right of the pivot should a 42 kg mass be placed to balance the beam?
3. A swimmer (62.5 kg) is standing at the end of a uniform diving board of length 5.00 m and mass 50.0 kg. The board is bolted on the left end and supported 1.50 m away by a fulcrum. Find the force acting on the board at the bolt and at the fulcrum.



4. A uniform 15 kg beam of length 4.0 m is supported against a wall as shown. A 25 kg object is suspended 3.0 m from the hinge P. What is the tension in the support cable?



5. A 12.0 kg uniform ladder that is 4.8 m long rests against a frictionless wall at an angle of 52° to the ground as shown. Calculate the force exerted on the ladder by the wall, if a 60.0 kg person is standing 4.0 m up the ladder.
6. What is the force at both supports, given the mass (m) is $2.00 \times 10^3 \text{ kg}$ and the mass of the beam is 150 kg?



Static Equilibrium

Sample Teaching and Assessment Strategies

Extension

Students may

- Investigate applications of torque in sports, including sports injuries.

Resources and Notes

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Static equilibrium (websites and videos)

Note

Static equilibrium is not covered in the *Pearson Physics* student resource.

Section Three: Specific Curriculum Outcomes

Unit 3: Fields

Focus

Forces that exert influence through space without contact are difficult to visualize. Historically, the notion of a field of influence which could be mapped and within which results are predictable, went a long way in explaining and relating a wide range of different forces (i.e., field theory).

There is a rich context for the study of fields in everyday experience. Students will describe and measure gravitational, electric, and magnetic forces and fields and analyze applications. Skill outcomes are addressed through scientific and research inquiry investigations.

Outcomes Framework

GCO 1 (STSE): Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

- 34.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
- 35.0 describe the importance of peer review in the development of scientific knowledge
- 36.0 explain how a major scientific milestone revolutionized thinking in the scientific communities
- 38.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology
- 44.0 analyze society's influence on scientific and technological endeavours
- 45.0 construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives
- 47.0 analyze technological systems to interpret and explain their structure and dynamics
- 49.0 identify various constraints that result in tradeoffs during the development and improvement of technologies

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

- 1.0 define and delimit problems to facilitate investigation
- 4.0 formulate operational definitions of major variables
- 6.0 develop appropriate sampling procedures
- 8.0 use library and electronic research tools to collect information on a given topic
- 9.0 select and integrate information from various print and electronic sources or from several parts of the same source
- 10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
- 11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
- 12.0 evaluate the relevance, reliability, and adequacy of data and data collection methods
- 13.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty
- 14.0 identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information
- 15.0 explain how data support or refute the hypothesis or prediction
- 16.0 identify and correct practical problems in the way a technological device or system functions
- 17.0 identify and evaluate potential applications of findings
- 18.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others
- 19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
- 20.0 synthesize information from multiple sources or from complex and lengthy texts and make inferences based on this information

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

- 32.0 describe gravitational fields as regions of space that affect mass
- 33.0 apply Newton's universal law of gravitation quantitatively
- 37.0 describe electric fields as regions of space that affect charge
- 39.0 apply Coulomb's law quantitatively
- 40.0 analyze electric circuits with respect to energy, voltage, current, resistance, and power
- 41.0 describe magnetic fields as regions of space that affect mass and charge
- 42.0 describe the magnetic field produced by current in both a solenoid and a long, straight conductor
- 43.0 analyze, qualitatively and quantitatively, the forces acting on a moving charge and on an electric current in a uniform magnetic field
- 46.0 analyze, qualitatively and quantitatively, electromagnetic induction by both a changing magnetic flux and a moving conductor
- 48.0 compare and contrast the way a motor and a generator function, using the principles of electromagnetism

GCO 4 (Attitudes): Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Students are encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- appreciate that the applications of science and technology can raise ethical dilemmas
- value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds
- show a continuing and more informed curiosity and interest in science and science-related issues
- acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research
- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations
- value the processes for drawing conclusions
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas
- project the personal, social, and environmental consequences of proposed actions

SCO Continuum

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

Science 9	Science 1206	Physics 3204
<ul style="list-style-type: none"> • explain the production of static electrical charges in some common materials • identify properties of static electrical charges • compare qualitatively static and current electricity • describe the flow of charge in an electrical circuit • describe series and parallel circuits involving varying resistance, voltage, and current 	<ul style="list-style-type: none"> • describe quantitatively the relationship among motion variables • analyze mathematically the relationship among displacement, velocity, and time • analyze graphically the relationship among displacement, velocity, and time for uniform and non-uniform motion • distinguish between instantaneous and average velocity • describe quantitatively the relationship among velocity, time, and acceleration 	<ul style="list-style-type: none"> • describe gravitational fields as regions of space that affect mass • apply Newton's universal law of gravitation quantitatively • describe electric fields as regions of space that affect charge • apply Coulomb's law quantitatively • analyze electric circuits with respect to energy, voltage, current, resistance, and power • describe magnetic fields as regions of space that affect mass and charge • describe the magnetic field produced by current in both a solenoid and a long, straight conductor • analyze, qualitatively and quantitatively, the forces acting on a moving charge and on an electric current in a uniform magnetic field • analyze, qualitatively and quantitatively, electromagnetic induction by both a changing magnetic flux and a moving conductor • compare and contrast the way a motor and a generator function, using the principles of electromagnetism

Suggested Unit Plan

September	October	November	December	January	February	March	April	May	June
Unit 1: Motion		Unit 2: Forces			Unit 3: Fields				Unit 4: Introduction to Quantum Physics
Skills Integrated Throughout									

Gravitational Fields

Outcomes

Students will be expected to

32.0 describe gravitational fields as regions of space that affect mass
[GCO 3]

32.1 describe gravitational fields by illustrating the source and directions of the lines of force

32.2 develop expressions used when measuring gravitational fields and forces

33.0 apply Newton's universal law of gravitation quantitatively
[GCO 3]

Focus for Learning

Gravitational, electric, and magnetic fields are addressed separately. However, students are expected to compare them, where appropriate.

Students should

- describe a gravitational field as a 3D region of space surrounding any object that has mass;
- understand that a test mass, when placed in a gravitational field, moves toward the centre of the object creating the field;
- draw the gravitational field lines with directional arrows around an object (See Figure 4.9, *Pearson Physics*, p. 200);
- define gravitational field strength, $\vec{g} = \frac{\vec{F}_g}{m_{\text{test}}}$;
- solve gravitational field problems to find a missing variable; and
- identify conditions that affect the magnitude of the gravitational field.

Present Newton's law of universal gravitation, $F_g = \frac{Gm_1m_2}{r^2}$,

where G is the universal gravitational constant ($6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$).

Students should apply Newton's law of universal gravitation to solve problems, solving for a missing variable when given all others.

Note, limit problems that require an altitude to be added to the radius of Earth to calculate the force of gravity.

Sample Performance Indicators

1. An astronaut stands on the surface of a planetoid and experiences a gravitational force of 120 N with a gravitation field at the surface of 1.6 N/kg. What is the mass of the astronaut?
2. What is the gravitational force of attraction between a 450 kg rock and a 1100 kg car with a separation distance of 3.5 m?
3. Calculate the mass of two identical objects that experience a gravitational force of attraction of $2.16 \times 10^{-10} \text{ N}$ when there is a 2.5 m separation distance between them.
4. Calculate the gravitational force on Felix Baumgartner (73.0 kg) as he began his free fall jump from an altitude of 38 969.3 m above the surface of Earth.

Gravitational Fields

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Engage students in a concept mapping activity to activate their preconceptions of fields.

Connection

Students may

- Carry out Quick Lab 4-1 and 4-2 (*Pearson Physics*, pp. 195, 198) to determine that coins of different shapes and sizes fall at the same rate and the relationship between the mass of an object and the gravitational force exerted on that object (i.e., weight).
- Represent Earth's and the Moon's gravitational field to illustrate the effect of mass on field strength.

Consolidation

Students may

- Solve problems such as the following:
 - You are standing on the surface of the Moon holding a 0.2 kg mass on a spring scale. The scale reads 0.324 N. Calculate the Moon's gravitational field strength.

Extension

Students may

- Analyze Figure 4.13 (*Pearson Physics*, p. 204) and solve problems such as the following:
 - What happens to the gravitational force between two masses when the distance between them doubles? one mass doubles and the other triples? or one mass doubles and the distance between them is halved?

Resources and Notes

Authorized

Appendices

- Appendix A

Pearson Physics Level 20
(Teacher Resource [TR])

- Unit II: Chapter 4 pp. 6-10

Pearson Physics (Student Resource [SR])

- pp. 194-208

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Gravitational fields and forces (websites and videos)

Field Theory

Outcomes

Students will be expected to

34.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
[GCO 1]

35.0 describe the importance of peer review in the development of scientific knowledge
[GCO 1]

Focus for Learning

This unit provides opportunities to address aspects of the nature of science.

As the unit progresses through gravitational, electric, and magnetic fields (i.e., classical field theory), students should be exposed to the historical development of these concepts. Exposure should include the experiments and ideas of individuals such as Cavendish, Coulomb, Faraday, Franklin, Gilbert, and Oersted.

The intent is to provide historical contexts for students to discuss the nature of science; how scientific knowledge develops. More specifically, they should use these historical contexts to explain

- the roles of evidence, theories, and paradigms; and
- the importance of peer review.

Treatment may be extended to introduce quantum field theory.

Attitudes

Encourage students to

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not, and
- value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds. [GCO 4]

*Field Theory***Sample Teaching and Assessment Strategies****Connection**

Teachers may

- Facilitate a class discussion related to how scientific knowledge develops.

Students may

- View the online resource *Understanding Science: how science really works*. Of particular relevance are the sections *Even theories change*, *Scrutinizing science: Peer review*, and *Scientific scrutiny*.
- Explore the historical development of Newton's gravitational force:
 - Discuss the contributions of Henry Cavendish, John Michell, and Edmund Halley to Newton's work.
 - Discuss the role of the torsion balance in determining the value of G .
- Explore the historical development of electric fields:
 - Discuss the contributions of Michael Faraday, Benjamin Franklin, and Charles de Coulomb.
 - Discuss the role of the torsion balance in the development of Coulomb's law.
- Explore the historical development of magnetic fields:
 - Discuss the contributions of William Gilbert, Michael Faraday, and Hans Christen Oersted.

Consolidation

Students may

- Tag physics-related articles explaining the development of scientific knowledge and the importance of peer review and add them to their STSE portfolio.

Resources and Notes**Authorized**

Pearson Physics Level 20 (TR)

- Unit II: Chapter 4 pp. 13-16

Pearson Physics (SR)

- pp. 194-208, 512-513, 528-530, 544-545, 582-587

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Understanding Science: How science really works (website)

Gravitational Fields

Outcomes

Students will be expected to

33.0 apply Newton's universal law of gravitation quantitatively [GCO 3]

36.0 explain how a major scientific milestone revolutionized thinking in the scientific communities [GCO 1]

Focus for Learning

Students should calculate the net gravitational force on one mass due to the presence of two other masses where the three masses are in a linear arrangement (e.g., celestial bodies).

Newton's law of universal gravitation can be used to derive an expression for the orbital speed of a satellite (*Pearson Physics*, pp. 277-278).

$$v = \sqrt{\frac{Gm_{\text{Earth}}}{r}}$$

While students are not expected to reproduce this derivation for assessment purposes, they should understand that the satellite's centripetal force is provided by the gravitational force due to the Earth; the satellite is in UCM.

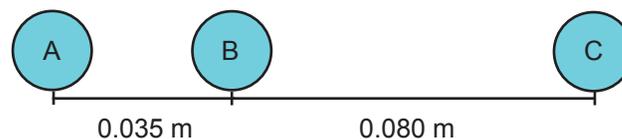
Students should calculate the orbital speed of an object

- where the radius of the object being orbited is negligible due to the large distance between them, and
- when given its altitude above Earth's surface.

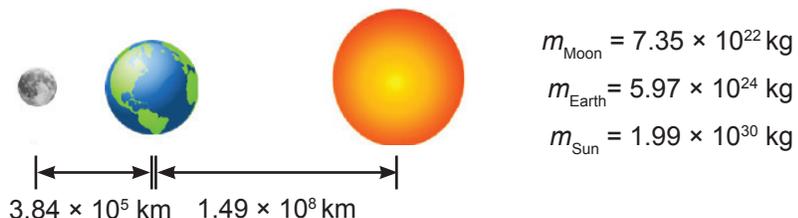
The significance of Newton's law of gravitation should be discussed. His law enabled the motion of objects on Earth and throughout the universe to be predicted and explained.

Sample Performance Indicators

1. Objects A, B, and C are in a linear arrangement as shown. Object A has a mass of 10.5 kg, B has a mass of 19.5 kg, and C has a mass of 11.1 kg. What is the net gravitational force exerted on
 - object A due to objects B and C, and
 - object B due to objects A and C?



2. What is the net gravitational force on Earth due to the Sun and Moon?



3. What is the speed of the International Space Station in its typical orbit, 350 km above Earth's surface?

Gravitational Fields

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present the Perimeter Institute video *Alice and Bob: Why Doesn't the Moon Fall Down?* to introduce orbits of celestial bodies.
- Present images or representations of space debris orbiting Earth and discuss problems associated with space junk.

Students may

- Carry out Design a Lab 5-4 (*Pearson Physics*, p. 276) to investigate the relationship between orbital period and orbital radius of planets orbiting the Sun.
- Discuss the role of gravitational force on Earth's tides and interplanetary travel.
- Research zero gravity flights and how these are used to train astronauts in preparation for upcoming missions.

Consolidation

Students may

- Solve problems such as the following:
 - Earth's moon is 3.844×10^5 km from Earth. Determine the orbital speed of the Moon.
 - What is the speed of a satellite orbiting Earth at an altitude of 22 500 km above the surface?
- Tag physics-related articles explaining how a scientific milestone revolutionized thinking in the scientific communities and add them to their STSE portfolio.

Extension

Students may

- Solve problems such as the following:
 - Neptune's average orbital radius is 4.50×10^{12} m from the Sun. The mass of the Sun is 1.99×10^{30} kg. What is Neptune's orbital speed and period?
 - A satellite is fired into orbit. Given $m_{\text{Earth}} = 5.97 \times 10^{24}$ kg and $r_{\text{Earth}} = 6.38 \times 10^6$ m, what altitude is required for geosynchronous orbit?

Resources and Notes

Authorized

Pearson Physics Level 20 (TR)

- Unit II: Chapter 4 pp. 13-20
- Unit III: Chapter 5 pp. 27-29

Pearson Physics (SR)

- pp. 203-215
- pp. 277-281

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Gravitational fields (websites and videos)

Artificial Satellites

Outcomes

Students will be expected to

- 1.0 define and delimit problems to facilitate investigation [GCO 2]
- 8.0 use library and electronic research tools to collect information on a given topic [GCO 2]
- 9.0 select and integrate information from various print and electronic sources or from several parts of the same source [GCO 2]
- 14.0 identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information [GCO 2]
- 19.0 *select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results* [GCO 2]
- 20.0 synthesize information from multiple sources or from complex and lengthy texts and make inferences based on this information [GCO 2]

Focus for Learning

Satellites perform a variety of tasks that make them almost indispensable to modern society.

Students are expected to complete a research project on artificial satellites. They should identify different types of artificial satellites (e.g., communications, Earth observation, navigational, scientific, weather) and select one to investigate in detail. Their investigation should identify

- the job performed;
- type of orbit occupied (e.g., geostationary, geosynchronous, low Earth, medium Earth, high Earth, polar);
- specific examples;
- construction and deployment costs; and
- expected lifespan.

Additionally, students should research an alternative technology that could be used in place of their selected satellite type and evaluate the cost and effectiveness of this technology compared with the satellite.

Findings should be communicated to classmates.

This project provides an opportunity to address and assess research-related skill outcomes (i.e., 1.0, 8.0, 9.0, 14.0, 19.0, 20.0). Completing the project in small collaborative groups would enable assessment of SCO 18.0 (i.e., communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others). Refer to the *Integrated Skills* unit for elaboration of these skill outcomes.

Attitudes

Encourage students to

- appreciate that the applications of science and technology can raise ethical dilemmas;
- acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research; and
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas. [GCO 4]

Artificial Satellites

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present the thought experiment “Newton’s cannonball”. Relate UCM to orbits. Using the idea of centripetal acceleration, objects can achieve a geosynchronous orbit.

Students may

- View images and representations of current satellites in orbit.
- Discuss applications of artificial satellites (e.g., cell phone communications, GPS navigation, weather forecasting).
- Distinguish between different types of orbits (e.g. geostationary, geosynchronous, low Earth, medium Earth, high Earth, polar).

Consolidation

Students may

- Compile a digital portfolio of information collected from various information sources.
- Evaluate sources of information. They may
 - ensure expertise (i.e., scientific or technological);
 - avoid ulterior motives (i.e., bias);
 - ensure information is current; and
 - check citations (i.e., content source) to ensure validity.

Resources and Notes

Authorized

Pearson Physics Level 20 (TR)

- Unit III: Chapter 5 p. 31

Pearson Physics (SR)

- pp. 284-286

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Artificial satellites (websites)

Electric Fields

Outcomes

Students will be expected to

37.0 describe electric fields as regions of space that affect charge
[GCO 3]

37.1 describe electric fields by illustrating the source and directions of the lines of force

37.2 describe electric fields in terms of like and unlike charges

34.0 *explain the roles of evidence, theories, and paradigms in the development of scientific knowledge*
[GCO 1]

35.0 *describe the importance of peer review in the development of scientific knowledge*
[GCO 1]

Focus for Learning

In Science 9, students learned that electric charges, when placed in proximity to each other, experience attractive or repulsive forces (i.e., law of electric charges). They should recognize that these forces exist due to the presence of electric fields.

Students should

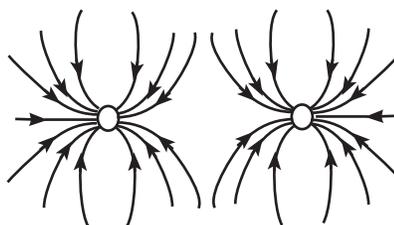
- describe an electric field as a 3D region of space surrounding a charged object in which another charged object experiences a force of attraction or repulsion;
- understand that the directions of field lines are determined by the direction a positive test charge moves when placed in an electric field; and
- draw the electric field lines with directional arrows around
 - single positive and negative charges,
 - two like charges,
 - two opposite charges, and
 - two parallel plates.

Figure 11.18 (*Pearson Physics*, p. 555) depicts electric field lines for each situation.

Readdress SCOs 34.0 and 35.0 (p. 114) highlighting the historical development of concepts related to electric fields.

Sample Performance Indicators

1. What are the charges of the objects in the diagram below?



2. Draw the electric field between two parallel plates of opposite charge and describe how a test charge is used to determine the field lines.

Electric Fields

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Activate students' prior knowledge from Science 9, related to electrostatics and the law of electric charges.

Connection

Teachers may

- Use an interactive online simulation (e.g., *PhET* - Charges and Fields) to demonstrate how electric field strength is determined.
- Demonstrate the electric field surrounding a charged object using an electroscope.

Students may

- Explore electric charges using an online simulation (e.g., *PhET* - Electric Field Hockey).
- Map electric fields using an online simulation (e.g., *PhET* - Charges and Fields).
- Explore a defibrillator as an application of electric fields.

Extension

Students may

- Draw field lines for a charged cylindrical ring, irregularly shaped solid conducting object, and a hollow conducting sphere.

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit VI: Chapter 11 pp. 7-10, 12-14

Pearson Physics (SR)

- pp. 542-547
- pp. 554-555

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Electric fields and forces (websites and videos)

Electric Fields

Outcomes

Students will be expected to

38.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology
[GCO 1]

16.0 identify and correct practical problems in the way a technological device or system functions
[GCO 2]

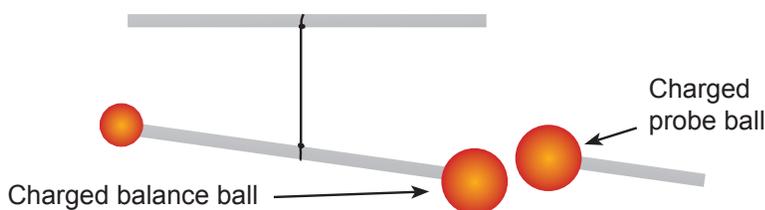
37.0 describe electric fields as regions of space that affect charge
[GCO 3]

37.3 develop expressions used when measuring electric fields and forces

39.0 apply Coulomb's law quantitatively
[GCO 3]

Focus for Learning

Coulomb hypothesized that the magnitude of an electrostatic force exerted by one charge on another depends on the magnitude of the charges and their separation distance. To test his hypothesis, he constructed a torsion balance (Figure 10.17, *Pearson Physics*, p. 528) to measure electrostatic forces. Students should construct and use a simple model of a torsion balance (e.g., string, dowelling, aluminum foil wrapped Styrofoam™ balls). Placing a charged probe in the vicinity of a charged balance ball should cause the balance to turn a small amount.



The torsion balance exemplifies how the invention of a technology may result in enhancement of scientific understanding.

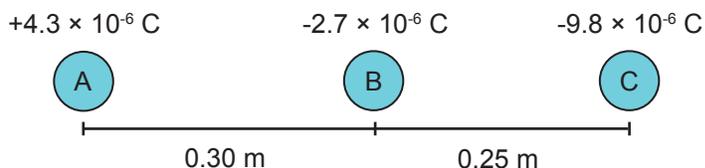
Students should apply Coulomb's law, $F_e = \frac{kq_1q_2}{r^2}$, to solve for a missing variable when given all others, where k is Coulomb's constant ($8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$). Note, the signs of charges should not be included in these calculations as magnitude is always positive. Determine force direction by whether the charge attracts or repels.

Additionally, students should

- compare and contrast Newton's universal law of gravitation and Coulomb's law; and
- calculate the net electric force on one charge due to the presence of two other charges where the three charges are in a linear arrangement. Note, it is recommended that the direction of net force be determined using an FBD.

Sample Performance Indicators

1. How far apart are the centres of a $-1.7 \times 10^{-6} \text{ C}$ charge and a $-2.0 \times 10^{-6} \text{ C}$ charge if the magnitude of the electric force is 0.49 N ?
2. Calculate the magnitude and direction of the net electric force on charge C due to charges A and B in the diagram shown below.



Electric Fields

Sample Teaching and Assessment Strategies

Connection

Students may

- Compare and contrast Coulomb's law and Newton's universal law of gravitation using a Venn diagram.

Consolidation

Students may

- Use their personally constructed torsion balance to investigate the relative electric force experienced when the magnitude of charge and/or the separation distance changes.
- Use an online simulation (e.g., *oPhysics* - Coulomb's Law with Two Charged Objects) to investigate Coulomb's Law and the influences of charge and separation distance on electric force.
- Solve problems such as the following:
 - Calculate the electric force between two charged spheres, each with a charge of -3.00×10^{-7} C, whose centers are separated by a distance of 2.00 mm.
 - Calculate the electric force between two electrons spaced 3.0×10^{-5} m apart if the charge on the electrons is -1.602×10^{-19} C.

Extension

Students may

- Attach two like charge balloons to opposite ends of a fishing line. Grasp the centre of the fishing line and allow the balloons to hang freely. Measure the distance between the centres of the two balloons and use vector analysis to calculate the repulsive force between them using the balloon's mass.
- Calculate the repulsive force between two protons in the nucleus of an atom.
- Solve problems such as the following:
 - The electric force between two charged objects is 0.10 N. What will be the new force if the charge on one object is made four times larger and the objects are moved three times further apart?

Resources and Notes

Authorized

- Pearson Physics Level 30* (TR)
- Unit VI: Chapter 10 pp. 15-20
- Pearson Physics* (SR)
- pp. 524-534

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Coulomb's law (websites and videos)

Electric Fields

Outcomes

Students will be expected to

37.0 describe electric fields as regions of space that affect charge
[GCO 3]

37.3 develop expressions used when measuring electric fields and forces

39.0 apply Coulomb's law quantitatively
[GCO 3]

Focus for Learning

Students should

- define electric field, $\vec{E} = \frac{\vec{F}_e}{q}$;
- solve electric field problems, solving for any missing variable; and
- compare and contrast expressions used for measuring electric and gravitational fields.

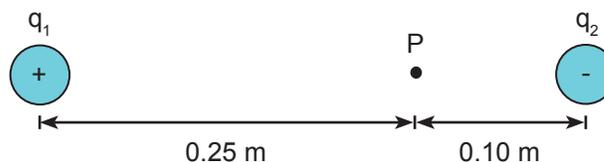
The expression for an electric field and Coulomb's law can be used to derive the electric field due to a point charge, $\vec{E} = \frac{kq}{r^2}$.

Students are not expected to derive this equation, but they should apply the equation to solve problems for any missing variable.

Additionally, students should determine the magnitude and direction of the net electric field, at a point, due to the presence of two point charges (limit to linear arrangements). They should determine the direction of the individual fields first, using the signs of the charges and the positive test charge. Then, calculate the magnitude of the net electric field. Note, the signs of charges need not be included in this calculation as magnitude is always positive.

Sample Performance Indicators

- What force is experienced by a 2.50×10^{-6} C test charge placed in a 2.92×10^4 N/C electric field?
- What is the magnitude of the electric field strength 6.7 m from a 6.0×10^{-6} C charged object?
- Two point charges are 0.35 m apart. The charge on q_1 is 2.4×10^{-9} C and the charge on q_2 is -1.6×10^{-8} C. Calculate the net electric field at point P.



Electric Fields

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present similarities and differences between gravitational and electric field strength.
- Demonstrate using an online simulation (e.g., *oPhysics* - Coulomb's Law with Two Charged Objects) how field strength varies with distance. Highlight the similarity to the inverse square law of gravitational fields.

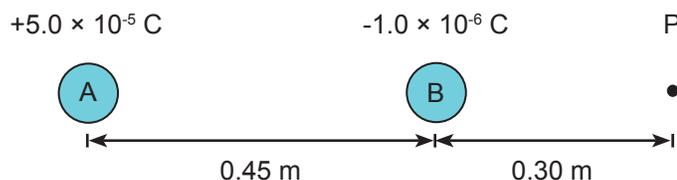
Students may

- Debate which natural force, gravity or electric force, is stronger. What evidence supports their position?

Consolidation

Students may

- Solve problems similar to the following
 - Two charged spheres, A and B, are arranged as shown. Calculate the magnitude and direction of the electric field strength at point P.



Resources and Notes

Authorized

- Pearson Physics Level 30* (TR)
- Unit VI: Chapter 11 pp. 9-12
- Pearson Physics* (SR)
- pp. 546-553

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Electric fields (websites and videos)

Electric Circuits

Outcomes

Students will be expected to

40.0 analyze electric circuits with respect to energy, voltage, current, resistance, and power
[GCO 3]

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
[GCO 2]

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
[GCO 2]

13.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty
[GCO 2]

Focus for Learning

Review in detail the concepts of voltage, current, resistance, and power, introduced in Science 9. In Physics 3204, students should

- define voltage (i.e., potential difference) as the energy required to move a charge from point A to point B, expressed as $V = \frac{\Delta E_p}{q}$; and
- define current as the quantity of charge that flows through a conductor in a given unit of time, expressed as $I = \frac{q}{t}$.

Show how $P = IV$ is derived using $P = \frac{\Delta E}{t}$, from Physics 2204, and the formulas for voltage and current. Note, students are not expected to derive $P = IV$.

Students should solve problems using $V = \frac{\Delta E_p}{q}$, $I = \frac{q}{t}$, and $P = IV$ separately and in combination.

Using $P = \frac{\Delta E}{t}$ to solve problems is not an expectation.

Physics 3204 uses electron current flow (i.e., from negative to positive terminal through the circuit) instead of conventional current flow. Conventional current will be used if students pursue further studies in physics.

Series and parallel circuits were investigated in Science 9 and students represented them using circuit diagrams. Review schematics for series and parallel circuits and the placement of ammeters and voltmeters within circuits to measure current and voltage.

Using physical materials, students should carry out a circuit investigation to determine the relationship between resistance, voltage, and current. As part of their investigation, students should

- compile, organize, and display their data;
- graph results and infer relationships among variables; and
- identify and explain sources of error.

Students may communicate findings in a lab report.

In addition to SCO's 10.0, 11.0, and 13.0, skill outcomes 6.0, 12.0, 16.0, 18.0, and 19.0 may be assessed. Refer to the *Integrated Skills* unit for elaboration.

Students should

- conclude that $R = \frac{V}{I}$ (i.e., Ohm's law), and
- solve problems, when given two of three variables, or a means of finding two.



Continued

Electric Circuits

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Use physical materials to construct a simple circuit and demonstrate how current and voltage are measured.

Students may

- Compare circuit investigation data, obtained using physical materials, with data obtained using an online simulation (e.g., *PhET* - Circuit Construction Kit DC). Accounting for discrepancies may lead to discussion of internal resistance.
- Draw schematics of constructed circuits.

Consolidation

Students may

- Analyze their graph depicting the relationship between resistance, voltage, and current and compare to graphs of other groups.
- Solve problems such as the following:
 - A 12 V car battery delivers 1.3×10^4 J of energy to the starter motor. How much charge does it deliver?
 - A lamp draws a current of 0.4 A. What is the amount of charge passing through the lamp in 10 seconds?
 - How long does it take for a current of 9.3×10^{-3} A to transfer a charge of 12 C?

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit VI: Chapter 11 pp. 16-18

Pearson Physics (SR)

- pp. 560-566

Teaching and Learning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/teaching-and-learning-strategies.html
 - *Circuits Lab*

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Electric circuits (websites and videos)

Notes

The magnifying glass icon is used throughout the unit to indicate investigations.



Electric circuits are not addressed in *Pearson Physics*.

Electric Circuits

Outcomes

Students will be expected to
40.0 analyze electric circuits with
respect to energy, voltage,
current, resistance, and
power
[GCO 3]

Focus for Learning**Attitude**

Encourage students to value the processes for drawing conclusions.
[GCO 4]

Sample Performance Indicators

1. If the potential difference across a battery is 6.0 V, how much energy is required to move 6.0×10^2 C of charge through a circuit?
2. Calculate the current produced for a light bulb with 1.0×10^5 C of charge passing through the filament for 2.5 hours.
3. What is the power rating of an electric kettle that draws a 12.5 A current in a 120 V circuit?
4. A 1200 W toaster is connected to a 120 V circuit. What is the resistance in the toaster?
5. 8.5×10^3 J of energy are required to move a certain quantity of charge through a potential difference of 1.2×10^2 V. If it takes 4.8 s for this charge to pass a point in the circuit, what is the current?

Electric Circuits

Sample Teaching and Assessment Strategies**Resources and Notes****Authorized**

Pearson Physics Level 30 (TR)

- Unit VI: Chapter 11 pp. 16-18

Pearson Physics (SR)

- pp. 560-566

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Electric circuits (websites and videos)

Electric Circuits

Outcomes

Students will be expected to

40.0 analyze electric circuits with respect to energy, voltage, current, resistance, and power
[GCO 3]

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts tables, graphs, and scatter plots
[GCO 2]

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
[GCO 2]

12.0 evaluate the relevance, reliability, and adequacy of data and data collection methods
[GCO 2]

15.0 explain how data support or refute the hypothesis or prediction
[GCO 2]

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
[GCO 2]

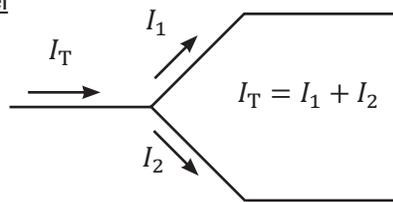
Focus for Learning

Students should conduct investigations to explore Kirchhoff's current and voltage laws in series and parallel circuits. For each circuit constructed, students should make predictions, take measurements, draw the schematic, and annotate the diagram with obtained values. They should infer:



Current in series $I_T = I_1 = I_2 = I_3 = \dots$

Current in parallel



Voltage in series $V_T = V_1 + V_2 + V_3 + \dots$

Voltage in parallel $V_T = V_1 = V_2 = V_3 = \dots$

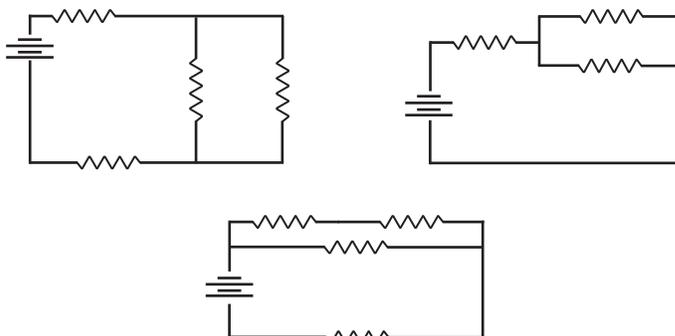
Resistance in series $R_T = R_1 + R_2 + R_3 + \dots$

Resistance in parallel $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$

These investigations provide opportunities to assess skill outcomes. In addition to SCOs 10.0, 11.0, 12.0, 15.0 and 19.0, teachers may assess SCOs 1.0, 2.0, 4.0, 5.0, 6.0, 7.0, 13.0, 16.0, and 18.0. Refer to the *Integrated Skills* unit for elaboration.

It is unlikely that students will infer the resistance relationship for parallel circuits through investigation. Present how this relationship can be derived from Kirchhoff's current and voltage laws and Ohm's law. Students are not expected to reproduce this derivation.

Students should state Kirchhoff's current and voltage laws and apply them to circuit analysis problems. Limit combination circuit analysis problems to a maximum of four resistors (examples below). Note, internal resistance is not considered.



Continued

Electric Circuits

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Provide physical materials for students to investigate and verify Kirchhoff's laws. Emphasis should be placed on safety, circuit construction, measurement, and analysis.
- Use a river analogy to aid discussion of Kirchhoff's current law (e.g., at a junction, a river will diverge and flow in different paths).
- Use the analogy of skiers, of equal mass, on a ski hill to aid discussion of Kirchhoff's voltage law (e.g., two skiers on a lift have an increase in potential, then they take different paths down the hill and meet at bottom [their potential drop is the same]).
- Relate Kirchhoff's voltage law to the law of conservation of energy (i.e., in closed systems or loops, the sum of the total energy is zero, hence, energy is conserved).

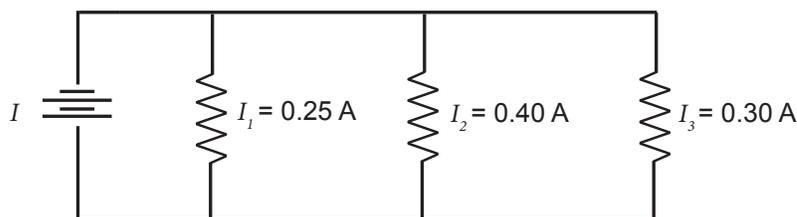
Students may

- Discuss the use of series and parallel circuits in home construction and electronics applications.

Consolidation

Students may

- Solve problems such as the following:
 - Sketch a circuit with three parallel 30.0 ohm resistors connected in series with a 10.0 ohm resistor and a 20.0 V battery. An ammeter measures the current through one of the resistors in parallel, and a voltmeter reads the voltage drop across the 10.0 ohm resistor. Determine the values shown by the ammeter and voltmeter.
 - What current is being drawn from the source in the circuit schematic below?



Resources and Notes

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Kirchhoff's laws (websites and videos)

Electric Circuits

Outcomes

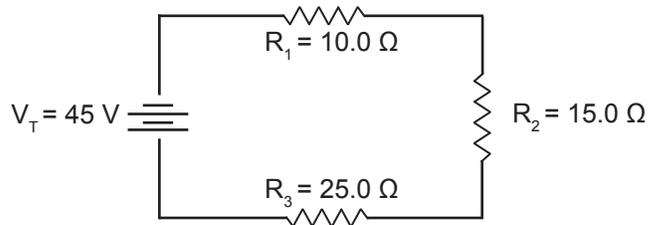
Students will be expected to
 40.0 analyze electric circuits with respect to energy, voltage, current, resistance, and power
 [GCO 3]

Focus for Learning

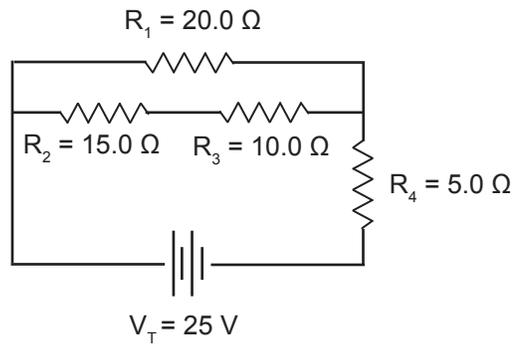
Additionally, students should calculate the power dissipated at any resistor in the combination circuit.

Sample Performance Indicators

- For the schematic below,
 - What is the voltage drop across R_1 ?
 - What is the power dissipated at R_3 ?



- For the schematic below,
 - What is the total resistance?
 - What is the voltage drop across R_1 ?
 - What is the current through R_3 ?
 - What is the power dissipated at R_2 ?



- A circuit has a current of 0.877 A and a potential difference of 13.66 V . What is the total resistance of the circuit?

Electric Circuits

Sample Teaching and Assessment Strategies**Resources and Notes****Suggested**

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Kirchoff's laws (websites and videos)

Magnetic Fields

Outcomes

Students will be expected to

41.0 describe magnetic fields as regions of space that affect mass and charge
[GCO 3]

41.1 describe magnetic fields by illustrating the source and directions of the lines of force

41.2 describe magnetic fields in terms of poles

34.0 *explain the roles of evidence, theories, and paradigms in the development of scientific knowledge*
[GCO 1]

35.0 *describe the importance of peer review in the development of scientific knowledge*
[GCO 1]

Focus for Learning

Students should

- describe a magnetic field as a 3D region of space surrounding a source in which other objects experience a force of attraction or repulsion;
- understand that a test compass, when placed in a magnetic field, will align with the direction of the field lines;
- draw the magnetic field lines with directional arrows around
 - a single bar magnet;
 - two bar magnets with like poles facing;
 - two bar magnets with opposite poles facing;
 - U-shaped magnets; and
 - Earth (Figure 12.7, *Pearson Physics*, p. 586, depicts most of these situations); and
- use domain theory to explain the structure and behaviour of magnets and magnetic materials.

Readdress SCOs 34.0 and 35.0 (p. 114) highlighting the historical development of concepts related to magnetic fields.

Sample Performance Indicators

1. Draw the magnetic field around the following bar magnet and describe how a test compass is used to determine the field lines.



2. Sketch the magnetic field around Earth with directional arrows.
3. Old magnets which have lost their strength can be remagnetized by placing them in a stronger magnetic field. How can this be explained using domain theory? Include a diagram to support your explanation.

Magnetic Fields

Sample Teaching and Assessment Strategies

Connection

Students may

- Research the development of magnetic field-related knowledge from the ancient Greeks to Michael Faraday.
- Use a compass to identify magnetic objects within their classroom. Alternatively, a mobile device compass application may be used.
- Compare and contrast the field lines associated with a test charge, test mass, and a test compass.

Consolidation

Students may

- Observe the magnitude and direction of magnetic fields using various magnets, iron filings, and a compass (Quick Lab 12-2, *Pearson Physics*, p. 584). Draw the magnetic field lines with directional arrows.
- Investigate the behaviour of magnets when placed in proximity to each other. Describe the behaviour using domain theory.

Extension

Students may

- Observe and illustrate the magnetic field lines around other types or arrangements of magnets (e.g., three poles in proximity to each other).

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit VI: Chapter 12 pp. 6-13

Pearson Physics (SR)

- pp. 580-592

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Magnetic fields and forces (websites and videos)

Magnetic Fields

Outcomes

Students will be expected to

42.0 describe the magnetic field produced by current in both a solenoid and a long, straight conductor [GCO 3]

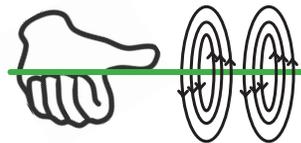
41.0 describe magnetic fields as regions of space that affect mass and charge [GCO 3]

41.3 develop expressions used when measuring magnetic fields and forces

Focus for Learning

Students should

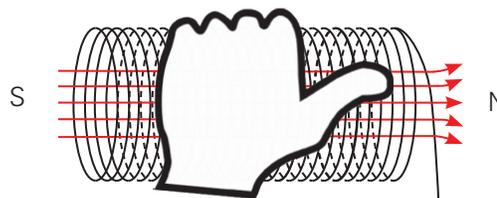
- recognize that magnetic fields are created from the movement of charges such as electrons;
- explain Oersted's principle for a straight conductor;
- apply left hand rule #1 (LHR1) to straight conductors to determine the direction of the magnetic field;



- apply the version of Biot's law below to solve magnetic field strength problems for current carrying wires, solving for any variable when given all others (μ_0 is the permeability constant for air [$4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$]);

$$B = \frac{\mu_0 I}{2\pi r}$$

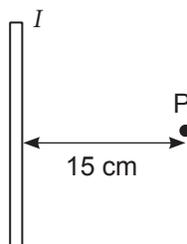
- apply left hand rule # 2 (LHR2) to solenoids;



- describe solenoids as electromagnets; and
- list factors that determine the strength of an electromagnet (i.e., current, number of loops, loop diameter, magnetic permeability of the core).

Sample Performance Indicator

- The magnetic field surrounding the current carrying wire below has a magnitude $2.9 \times 10^{-5} \text{ T}$, and is directed into the page at point P. Calculate the magnitude and direction of the current in the wire.



Magnetic Fields

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Demonstrate the presence of a magnetic field around current carrying conductor using iron filings.
- Discuss observations when driving beneath power lines while listening to AM radio frequencies.
- Present videos depicting how large hadron colliders work (i.e., how charged particles interact with magnetic fields).
- Discuss reversals in Earth's magnetic field.

Students may

- Discuss similarities and differences in expressions used to measure gravitational, electric, and magnetic fields and forces.
- Investigate how distance affects magnetic field strength using a compass placed near a current carrying conductor.
- Use research inquiry to explore Maglev (i.e., magnetically levitated) trains and/or hyperloop transportation technologies.

Consolidation

Students may

- Solve problems such as the following:
 - What is the magnetic field 2.5 cm away from a long straight conductor carrying 7.6 A of current?
 - What current is necessary to generate a magnetic field of 3.0×10^{-6} T at a distance of 1.6 cm?
 - What is the magnitude of the magnetic field midway between two wires spaced 1.6 cm apart if both wires are carrying a current of 3.5 A in opposite directions?

Extension

Students may

- Solve problems such as the following:
 - An electron travelling at 4.2×10^6 m/s enters a uniform magnetic field at a right angle. When inside the field, the curved path of the electron has a radius of 5.3×10^{-2} m. Calculate the magnitude of the magnetic field.

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit VI: Chapter 12 p. 11

Pearson Physics (SR)

- pp. 587-590

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Magnetic fields (websites and videos)

Notes

Biot's law is not addressed in *Pearson Physics*.

Magnetic Fields

Outcomes

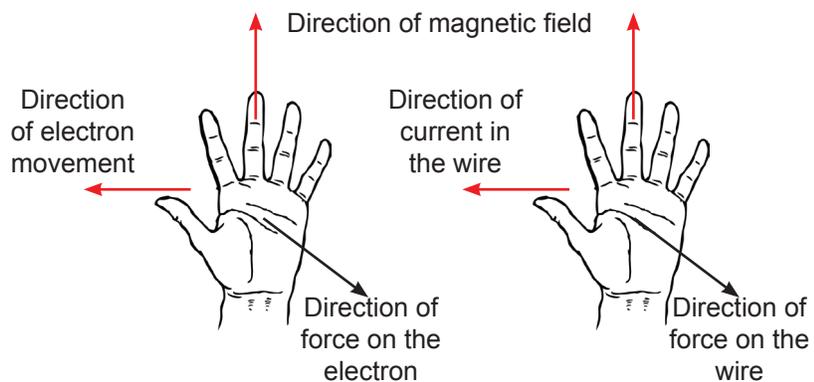
Students will be expected to

43.0 analyze, qualitatively and quantitatively, the forces acting on a moving charge and on an electric current in a uniform magnetic field [GCO 3]

Focus for Learning

Students should

- calculate the magnitude of the magnetic force acting on a moving charge (i.e., deflection of a charged particle) within a magnetic field, using $F = qvB\sin\theta$;
- calculate the magnitude of the magnetic force on a current carrying wire, using $F = BIL\sin\theta$;
- use Left hand rule #3 (LHR3) to determine the direction of the magnetic force in the cases above;

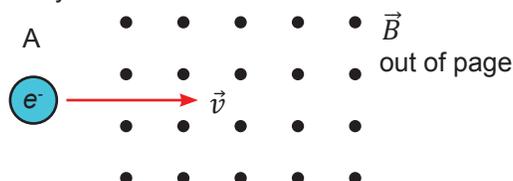


- recognize that a charged particle, initially moving perpendicular to the magnetic field lines, will experience a deflection force and follow a circular path; and
- recognize that a charged particle moving parallel to the magnetic field lines will experience no force and, therefore, not deflect.

Students are not expected to derive expressions for magnetic force. For positive charges, students should use a right hand rule.

Sample Performance Indicators

1. An electron moving at 2.00×10^6 m/s through a 1.50 T magnetic field experiences a force of 2.40×10^{-13} N. What is the angle between the electron's path and the magnetic field lines?
2. A wire of length 0.20 m is placed in a 0.25 T magnetic field at an angle of 35° to the field. What is the current in the wire if it experiences a force of 0.75 N?
3. A magnetic field strength of 0.30 T emerges from the page (shown by the series of dots). An electron with a negative charge of 1.602×10^{-19} C enters the magnetic field at 6.0×10^6 m/s [right]. What are the magnitude and direction of the force exerted on the electron by the field?



Magnetic Fields

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Present videos demonstrating jumping wires when current flows.

Students may

- Use research inquiry to explore auroras (i.e., Aurora Borealis, Aurora Australis).

Consolidation

Students may

- Solve problems such as the following:
 - An electron shot into a magnetic field of 0.020 T at 5.6×10^6 m/s, has a force of 8.96×10^{-15} N. At what angle does the electron enter the field?
 - An electron is projected perpendicularly into a magnetic field with a velocity of 3.3×10^7 m/s and experiences a force of 1.3×10^{-13} N. What is the magnitude of the magnetic field?
 - What force is exerted on a straight conductor of length 1.5 m suspended in a magnetic field of strength 3.2×10^{-3} T with a current of 2.0 A if the wire is moving perpendicular to the field.
 - Calculate the current required to generate a force of 6.0×10^{-6} N in a 5.5 m long straight wire suspended in a magnetic field of 3.4×10^{-6} T if the wire is at an angle of 30° to the field.
 - What is the magnetic field if there is a force of 1.5 N generated on 17 m of copper conductor with a 2.0 A current when the wire is perpendicular to the magnetic field?

Extension

- Solve problems connecting the motor principle to UCM such as the following:
 - An electron travels with a speed of 2.00×10^6 m/s in a plane perpendicular to a 1.00×10^{-3} T magnetic field. What is the radius of the electron's path?

Resources and Notes

Authorized

- Pearson Physics Level 30* (TR)
- Unit VI: Chapter 12 pp. 13-21
- Pearson Physics* (SR)
- pp. 593-608

Magnetic Fields

Outcomes

Students will be expected to

44.0 analyze society's influence on scientific and technological endeavours [GCO 1]

45.0 construct arguments to support a decision or judgement, using examples and evidence and recognizing various perspectives [GCO 1]

1.0 *define and delimit problems to facilitate investigation* [GCO 2]

17.0 *identify and evaluate potential applications of findings* [GCO 2]

20.0 *synthesize information from multiple sources or from complex and lengthy texts and make inferences based on this information* [GCO 2]

Focus for Learning

The impact of science and technology on society is evident. But society also influences scientific and technological endeavours.

Students should consider these influences while researching societal concerns regarding possible health effects from exposure to artificial electromagnetic fields (e.g., power lines, telecommunications). They should

- narrow their research focus to facilitate investigation;
- use research tools to collect information on their topic;
- identify and apply criteria, including bias, to evaluate sources of information and evidence; and
- construct evidence-based arguments to support a decision or judgement.

A fictitious context (e.g., a proposal to construct a high voltage power transmission line through a residential area) may be provided to stimulate debate.

In addition to SCOs 1.0, 17.0, and 20.0, teachers may assess skill outcomes 8.0, 9.0 and 14.0. Refer to the *Integrated Skills* unit for elaboration of these skills.

Attitudes

Encourage students to

- appreciate that the applications of science and technology can raise ethical dilemmas;
- show a continuing and more informed curiosity and interest in science and science-related issues;
- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations; and
- project the personal, social, and environmental consequences of proposed action values the processes for drawing conclusions. [GCO 4]

Magnetic Fields

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Facilitate a discussion regarding natural and artificial sources of electromagnetic fields in everyday life.
- Review criteria for evaluating sources of scientific or technological information.
- Model how to iteratively narrow a research topic, defining and delimiting to construct a manageable research question.

Students may

- Identify multiple perspectives with respect to issues involving electromagnetic fields.
- Identify careers that may involve increased exposure to electromagnetic fields.
- Explore efforts to mitigate exposure to electromagnetic fields.
- Brainstorm ways society can influence scientific and technological development.

Consolidation

Teachers may

- Facilitate a class debate regarding a fictitious context (e.g., constructing a mobile phone communications tower adjacent to an elementary school). Ask students to construct arguments from varying perspectives on the issue.

Students may

- Identify areas of further study related to health effects from exposure to electromagnetic fields.
- Tag physics-related articles illustrating society's influence on science and technology and or multiple perspectives on issues.

Resources and Notes

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Electromagnetic fields (websites)

Electromagnetic Induction

Outcomes

Students will be expected to

- 46.0 analyze, qualitatively and quantitatively, electromagnetic induction by both a changing magnetic flux and a moving conductor
[GCO 3]
- 4.0 *formulate operational definitions of major variables*
[GCO 2]
- 6.0 *develop appropriate sampling procedures*
[GCO 2]
- 11.0 *interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables*
[GCO 2]
- 17.0 *identify and evaluate potential applications of findings*
[GCO 2]
- 18.0 *communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others*
[GCO 2]
- 19.0 *select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results*
[GCO 2]

Focus for Learning

Students should investigate factors (i.e., number of loops in the coil, coil diameter, coil density, magnet strength, relative speed of motion between the magnet and coil) that influence the effect produced when there is relative motion between an external magnetic field and a conducting wire (Inquiry Lab 12-6 [*Pearson Physics*, p. 612] provides a model procedure).

Students should devise and carry out procedures to investigate each factor; observing the direction and relative magnitude of the galvanometer's deflection. They should conclude that

- current is only produced when there is relative motion;
- current increases when coil diameter decreases, and the number of loops, coil density, magnet strength, and relative motion increases, and
- the direction of deflection changes with the direction of relative motion.

In addition to skill outcomes 4.0, 6.0, 11.0, 17.0, and 19.0, teachers may assess SCOs 3.0, 10.0, 12.0, 16.0, and 18.0. Refer to the *Integrated Skills* unit for elaboration of skill outcomes.

Additionally, students should

- describe Faraday's law;
- investigate the relationship between the motor effect and the generator effect using a length of copper pipe and cylindrical rare earth magnets (Inquiry Lab 12-7 [*Pearson Physics*, p. 616] provides a model procedure. Teachers may assess skill outcomes 10.0, 11.0, and 13.0);
- recognize that the direction of the induced current in a solenoid produces a magnetic field that opposes the magnetic field inducing it (Lenz's law); and
- apply Lenz's law to predict the direction of the induced current, the direction of motion of the magnet, or the polarity of the magnet, when given the other two.

Treatment should also include how a changing magnetic field can induce a current. Students should analyze Faraday's induction coil (Figure 12.40 *Pearson Physics*, p. 615) and describe how a change in the current in the primary coil produces a magnetic field which induces a temporary current in the secondary coil.

Attitudes

Encourage students to

- value the processes for drawing conclusions; and
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas. [GCO 4]



Continued

Electromagnetic Induction

Sample Teaching and Assessment Strategies

Connection

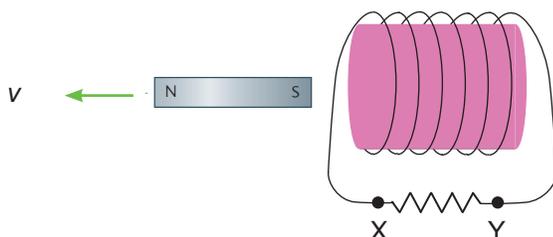
Students may

- Create coils of conducting wire by wrapping the wire around a cylinder of sufficient diameter to allow a bar magnet to be inserted.
- Devise procedures for each factor investigated that detail how variables are defined (e.g., 10, 20, and 30 loop coils) and describe sampling techniques.

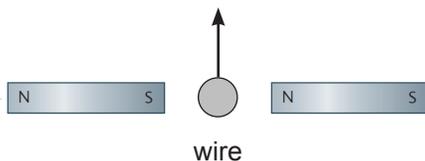
Consolidation

Students may

- Solve problems such as the following:
 - A bar magnet is moved away from a coil as shown. What is the direction of the induced current through the resistor and the polarity of the left end of the coil?



- What is the direction of the induced current in the wire when it is moved in the direction indicated?



- Explore Faraday's law using an online simulation (e.g., *PhET - Faraday's Law*).

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit VI: Chapter 12 pp. 21-23, 26-27

Pearson Physics (SR)

- pp. 609-613, 617-620

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Electromagnetic induction (websites and videos)

Electromagnetic Induction

Outcomes

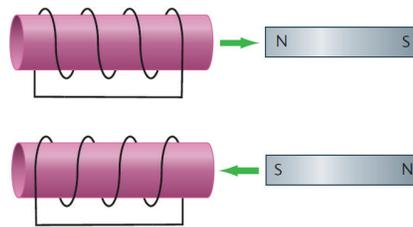
Students will be expected to

46.0 analyze, qualitatively and quantitatively, electromagnetic induction by both a changing magnetic flux and a moving conductor
[GCO 3]

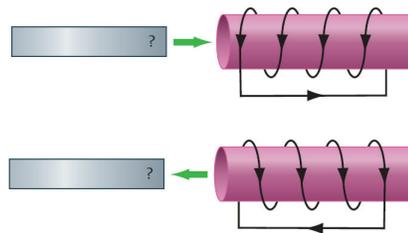
Focus for Learning

Sample Performance Indicators

1. The magnet is moved in the direction indicated for each of the following coils. On each diagram, label the N and S poles of the electromagnet induced coil and the direction of the induced current.



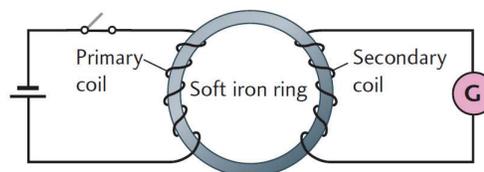
2. Magnets are moved as shown below. The direction of the induced current is shown on each coil. Show the polarity of the electromagnet and determine the pole of the magnet that is closest to the coil.



3. A diagram of Faraday's induction coil is pictured below. Clearly annotate the diagram with the following at the instant the switch in the primary is opened:

- direction of the current in the primary coil,
- polarity of the magnetic field surrounding the primary coil, and
- polarity of the magnetic field surrounding the secondary coil.

Include a brief explanation for each choice.



Electromagnetic Induction

Sample Teaching and Assessment Strategies**Resources and Notes****Authorized**

Pearson Physics Level 30 (TR)

- Unit VI: Chapter 12 pp. 21-23, 26-27

Pearson Physics (SR)

- pp. 609-613, 617-620

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Electromagnetic induction (websites and videos)

Motors and Generators

Outcomes

Students will be expected to

47.0 analyze technological systems to interpret and explain their structure and dynamics
[GCO 1]

48.0 compare and contrast the way a motor and a generator function, using the principles of electromagnetism
[GCO 3]

49.0 identify various constraints that result in tradeoffs during the development and improvement of technologies
[GCO 1]

Focus for Learning

Introduce alternating current (AC) and direct current (DC) electric motors as applications of electromagnetism. Students should

- recognize that a motor converts electrical energy into mechanical energy of rotation;
- identify the components of AC and DC motors and explain how they work (See Fig. 12.32, *Pearson Physics*, p. 609);
- explain differences in structure and functioning of AC and DC motors (e.g., slip rings vs. commutator [split ring]), and
- given the direction of current in the armature and/or the external circuit, determine the direction of rotation of the armature using LHR3.

Introduce generators as an application of electromagnetic induction. Students should

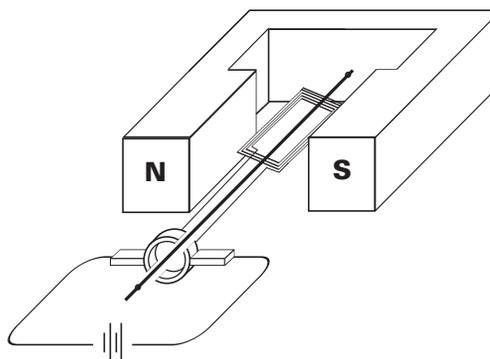
- recognize that a generator converts mechanical energy of rotation into electrical energy (opposite to a motor);
- explain differences in structure and functioning of AC and DC generators; and
- given the direction of rotation of the armature, determine the current direction through the armature and/or the external circuit using LHR1 or LHR3 and Lenz's law.

Additionally, students should compare and contrast the way a motor and a generator function.

Use research inquiry to briefly explore the development and improvement of electric motors for use in the automotive industry. Identify constraints (e.g., fuel efficiency vs. cost of the vehicle, physical battery size, availability of charging stations, time to charge, driving distance per charge, efficiency in temperature extremes).

Sample Performance Indicator

- Describe the structure and functioning of the device below and identify the direction it will rotate.



Motors and Generators

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate the operation of a hand-held electric generator connected to a multimeter.

Connection

Students may

- Brainstorm applications of AC and DC motors.
- Compare and contrast the operation of an alternator (i.e., vehicle charging system) with a DC generator and motor.

Consolidation

Students may

- Construct simple models of motors or generators (e.g., Building a Model of a Direct Current Generator [*Pearson Physics*, p. 624]).
- Analyze small electric motors and generators.
- Participate in a design challenge to construct a simple generator that produces the most current.
- Tag physics-related articles that analyze the structure and dynamics of technological systems or identify constraints in their development and improvement.
- Analyze technological applications of electromagnetic induction, explaining their structure and dynamics (e.g., electric meters [ammeters, galvanometers, voltmeters], electric motors, loud speakers, electromagnets, magnetohydrodynamic propulsion systems).

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit VI: Chapter 12 pp. 21, 25-26

Pearson Physics (SR)

- pp. 608, 615-617

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Motors and generators (websites and videos)

Section Three:
Specific Curriculum Outcomes

Unit 4: Introduction to Quantum Physics

Focus

Classical physics includes most of the ideas about light, energy, heat, forces, and electricity and magnetism up to about 1900. It seemed as though everything in Physics had been explained, however, new observations of phenomena and certain experimental results posed difficulties for classical physics. To resolve these difficulties would require new, sometimes radical, ideas.

This unit emphasizes the nature of science. In particular, how scientific knowledge develops and how scientific milestones revolutionize scientific thinking.

Outcomes Framework

GCO 1 (STSE): Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

- 34.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
- 36.0 explain how a major scientific milestone revolutionized thinking in the scientific communities
- 47.0 analyze technological systems to interpret and explain their structure and dynamics
- 50.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
- 53.0 compare processes used in science with those used in technology
- 54.0 analyze and describe examples where technologies were developed based on scientific understanding

GCO 2 (Skills): Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

- 4.0 formulate operational definitions of major variables
- 6.0 develop appropriate sampling procedures

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

- 51.0 describe how the quantum energy concept explains blackbody radiation and the photoelectric effect
- 52.0 explain qualitatively and quantitatively the photoelectric effect
- 55.0 explain the Compton effect using the laws of mechanics, the conservation of momentum, and the nature of light
- 56.0 explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts
- 57.0 explain the relationship between the energy levels in Bohr's model, the energy difference between the levels, and the energy of the emitted photons
- 58.0 use the quantum mechanical model to explain natural luminous phenomena
- 59.0 summarize the evidence for the wave and particle models of light
- 60.0 explain the de Broglie hypothesis

GCO 4 (Attitudes): Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Students are encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds
- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

SCO Continuum

GCO 3 (Knowledge): Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

Science 1206	Physics 2204	Physics 3204
<ul style="list-style-type: none"> describe quantitatively the relationship among motion variables analyze mathematically the relationship among displacement, velocity, and time analyze graphically the relationship among displacement, velocity, and time for uniform and non-uniform motion distinguish between instantaneous and average velocity describe quantitatively the relationship among velocity, time, and acceleration 	<ul style="list-style-type: none"> apply the wave equation to explain and predict the behaviour of waves explain qualitatively and quantitatively the phenomena of wave interference, reflection, and diffraction compare and describe the properties of electromagnetic radiation and sound explain qualitatively and quantitatively the Doppler-Fizeau effect explain qualitatively and quantitatively the phenomena of wave refraction apply the laws of reflection and the laws of refraction to predict wave behaviour 	<ul style="list-style-type: none"> describe how the quantum energy concept explains blackbody radiation and the photoelectric effect explain qualitatively and quantitatively the photoelectric effect explain the Compton effect using the laws of mechanics, the conservation of momentum, and the nature of light explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts explain the relationship between the energy levels in Bohr's model, the energy difference between the levels, and the energy of the emitted photons use the quantum mechanical model to explain natural luminous phenomena summarize the evidence for the wave and particle models of light explain the de Broglie hypothesis

Suggested Unit Plan

September	October	November	December	January	February	March	April	May	June
Unit 1: Motion		Unit 2: Forces			Unit 3: Fields			Unit 4: Introduction to Quantum Physics	
Skills Integrated Throughout									

Quantum Energy Concept

Outcomes

Students will be expected to

50.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
[GCO 1]

34.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
[GCO 1]

36.0 explain how a major scientific milestone revolutionized thinking in the scientific communities
[GCO 1]

51.0 describe how the quantum energy concept explains blackbody radiation and the photoelectric effect
[GCO 3]

Focus for Learning

This unit provides significant opportunities to address outcomes related to the nature of science (i.e., SCOs 50.0, 34.0, 36.0). These STSE outcomes should to be addressed throughout the unit.

When exploring the work of Planck, Einstein, Compton, de Broglie, and Bohr, students should

- explain the difficulties that certain experimental results posed for classical physics, and
- explain how those difficulties were resolved using new ideas.

To introduce the unit, review how Young's double slit experiment, from Physics 2204, showed that light behaves as a wave. Inform students that the same experiment done with electrons, believed to behave as classical particles, showed that they exhibit wave-like characteristics as well. Students should recognize that sometimes reality does not behave as expected.

One of the first phenomenon to produce unexpected experimental results was blackbody radiation. Students should

- describe a blackbody and recognize that higher temperature bodies emit shorter wavelengths of light, and
- compare the blackbody radiation curve predicted using classical theory with observed intensity curves at different temperatures (Figure 14.4 *Pearson Physics*, p. 705).

Raleigh and Jeans developed a mathematical model, based on principles of classical physics, to describe blackbody radiation, but problems were revealed (i.e., the ultraviolet catastrophe):

- There was significant disagreement between calculated and observed values for shorter wavelengths.
- Classical physics predicted that light intensity would increase with increased temperature, however, experimental observations showed a drop in intensity after the peak.

In 1900, Planck resolved these difficulties by developing an equation for blackbody radiation that was in complete agreement with experimental results at all wavelengths. Students should

- describe Planck's hypothesis and define quantum;
- define photon;
- use $E = hf$ and $E = \frac{hc}{\lambda}$ to solve problems, where

$h = 6.63 \times 10^{-34}$ J·s (Planck's constant); and

- recognize the quantum energy concept as a major scientific milestone that revolutionized thinking.

Continued

Quantum Energy Concept

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present videos (e.g., *The Challenge of Quantum Reality: Parts 1-3*, Perimeter Institute) to introduce quantum energy.

Connection

Teachers may

- Ask students to complete the following table as phenomenon are addressed identifying whether observations support either the wave or particle model of light, or both.

Phenomenon	Wave Model	Particle Model
Reflection		
Refraction		
Interference		
Diffraction		
Blackbody radiation		
Photoelectric effect		
Compton effect		
Line spectra		

- Present videos depicting the heating of iron and the different colours of light emitted.
- Compare the Raleigh and Jeans mathematical model with Planck's equation.

Students may

- Describe Young's double slit experiment and its relationship to the particle and wave models of light.

Consolidation

Students may

- Interpret graphs comparing the classical prediction of blackbody radiation to observed experimental curves for objects at different temperatures (e.g., Figure 14.4 *Pearson Physics*, p. 705).
- Discuss how the concept of quantum energy revolutionized thinking in scientific communities.
- Create an infographic to describe the historical development of quantum theory. Add to the infographic as the unit progresses.
- Tag physics-related articles that
 - explain how scientific knowledge evolves;
 - explain the role of evidence, theories and paradigms in that development of scientific knowledge; and
 - explain how scientific milestones revolutionized thinking.

Resources and Notes

Authorized

Pearson Physics Level 30
(Teacher Resource [TR])

- Unit VII: Chapter 14 pp. 2-10, 26-30

Pearson Physics (Student Resource [SR])

- pp. 634-640, 702-710, 737-740

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Quantum energy concept (websites and videos)

Quantum Energy Concept

Outcomes

Students will be expected to

51.0 describe how the quantum energy concept explains blackbody radiation and the photoelectric effect [GCO 3]

52.0 explain qualitatively and quantitatively the photoelectric effect [GCO 3]

4.0 formulate operational definitions of major variables [GCO 2]

6.0 develop appropriate sampling procedures [GCO 2]

53.0 compare processes used in science with those used in technology [GCO 1]

54.0 analyze and describe examples where technologies were developed based on scientific understanding [GCO 1]

47.0 analyze technological systems to interpret and explain their structure and dynamics [GCO 1]

Focus for Learning

Students should investigate the photoelectric effect using an online simulation. A recommended procedure is described in the *Photoelectric Effect: Simulation Lab* teaching and learning video. The recommended investigation provides opportunity to assess skill outcomes 4.0, 6.0, 10.0, 11.0, 13.0, 18.0, and 19.0. Refer to the *Integrated Skills* unit for elaboration of these outcomes.



Through investigation, students should observe that

- photoelectrons are not emitted when the light frequency falls below the threshold frequency, no matter how great the light intensity; and
- the kinetic energy of the photoelectrons is independent of the intensity of the incident light.

These observations could not be explained using classical physics.

Einstein resolved these difficulties using Planck's idea of quanta and proposed that light should be thought of as particles (i.e., photons).

Students should

- describe the photoelectric effect;
- define work function, stopping potential, and threshold frequency;
- interpret graphs (e.g., Figure 14.12 *Pearson Physics*, p. 714) to determine the work function for metal surfaces and calculate Planck's constant (i.e., slope); and
- solve problems using $hf = W_0 + E_k$ and $E_{k_{\max}} = eV_{\text{stop}}$.

Note, when solving problems, students are expected to be able to convert between electron volts and joules ($1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$) and wavelength and frequency ($c = f\lambda$).

The evolution of scientific knowledge often leads to the development of new technologies (e.g., photocells). Students should briefly research applications of photocells and explain their structure and function. This research inquiry provides an opportunity to address STSE outcomes 53.0, 54.0, and 47.0 and numerous skill outcomes (e.g., 8.0, 9.0, 19.0, 20.0).

Attitudes

Encourage students to

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not;
- value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds; and
- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations. [GCO 4]

Continued

Quantum Energy Concept

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Demonstrate the photoelectric effect using a zinc metal plate (e.g. Quick Lab 14-2 Discharging a Zinc Plate Using UV Light, *Pearson Physics*, p. 711). Alternatively, an aluminum pop can could be used. Using a red light could demonstrate how insufficient energy does not produce an effect.
- Introduce the concept of work function using an analogy, such as trying to kick a soccer ball that is buried in sand. The energy of the incoming photons of light is analogous to the energy of the incoming player's foot. To kick the ball, the incoming foot must loosen the ball from the sand and any remaining energy moves the ball (i.e., gives the ball kinetic energy). Similarly, the energy of the incident photons must be sufficient to free the electron from the metal plate and get the electron moving.

Students may

- Use an online simulator (e.g., *The Physics Aviary - Photoelectric Effect Lab*) to explore the photoelectric effect.
- As part of the photoelectric effect simulation investigation
 - graph the photon frequency vs. stopping voltage for each metal selected,
 - draw a line of best fit
 - calculate the work function from the x-intercept,
 - compare calculated values of work function with accepted values (Table 14.1, *Pearson Physics*, p. 712), and
 - calculate percentage error.
- Construct a photocell.

Consolidation

Teachers may

- Facilitate a cooperative jigsaw activity to research applications of photocells.

Students may

- Conduct an investigation to measure Planck's constant using a simple circuit and LEDs (i.e., *Perimeter Institute - Measuring Planck's Constant*).
- Create a graphic organizer to describe the photoelectric effect, threshold frequency, work function, and stopping potential.
- Distinguish between science and engineering processes in a graphic organizer.
- Add to the infographic describing the historical development of quantum theory introduced on page 155.

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit VII: Chapter 14 pp. 10-15

Pearson Physics (SR)

- pp. 711-720

Teaching and Learning Strategies

- www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/teaching-and-learning-strategies.html
 - *Photoelectric Effect: Simulation Lab*

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Photoelectric effect (websites and videos)

Notes

The magnifying glass icon is used throughout the unit to indicate investigations.



Quantum Energy Concept

Outcomes

Students will be expected to

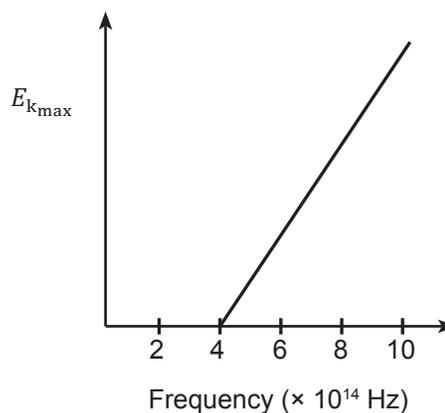
51.0 describe how the quantum energy concept explains blackbody radiation and the photoelectric effect [GCO 3]

52.0 explain qualitatively and quantitatively the photoelectric effect [GCO 3]

Focus for Learning

Sample Performance Indicators

1. Calculate the energy of a single photon if it has a frequency of 1.5×10^{15} Hz.
2. What is the wavelength of a photon having an energy of 2.12 eV?
3. Calculate the threshold frequency that causes photoelectric emission from a metal surface having a work function of 2.00 eV.
4. If the stopping potential of a photoelectric cell is 5.60 V, what is the maximum kinetic energy of the photoelectrons emitted?
5. A metal with a work function of 4.56 eV is illuminated by light with a wavelength of 1.7×10^{-7} m. What is the maximum kinetic energy of the emitted electrons?
6. In a photoelectric effect experiment, light is shone on a metal surface. The graph below illustrates the maximum kinetic energy of ejected electrons versus frequency of the incident light of the photons. Determine the work function of the metal.



Quantum Energy Concept

Sample Teaching and Assessment Strategies**Resources and Notes****Authorized**

Pearson Physics Level 30 (TR)

- Unit VII: Chapter 14 pp. 2-15, 26-30

Pearson Physics (SR)

- pp. 634-640, 702-720

Photon Momentum and Wave Properties of Matter

Outcomes

Students will be expected to

55.0 explain the Compton effect using the laws of mechanics, the conservation of momentum, and the nature of light [GCO 3]

56.0 explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts [GCO 3]

57.0 explain the relationship between the energy levels in Bohr's model, the energy difference between the levels, and the energy of the emitted photons [GCO 3]

58.0 use the quantum mechanical model to explain natural luminous phenomena [GCO 3]

Focus for Learning

Einstein further proposed that photons have momentum, $p = \frac{hf}{c}$, which he derived using $E = mc^2$ and conservation of momentum. Compton and his colleagues independently carried this idea further. Their experiments could not be explained using the classical wave theory of light, however, they could be explained by treating X-rays as photons.

Students should

- describe Compton's X-ray scattering experiment and results (Fig. 14.16 *Pearson Physics*, p. 721);
- understand how the laws of conservation of energy and momentum can be applied to the X-ray and the electron;
- understand how Compton's expression for photon momentum, $p = \frac{h}{\lambda}$, can be derived using $p = \frac{hf}{c}$ and $c = f\lambda$; and
- solve problems using $p = \frac{h}{\lambda}$ (Note, limit treatment to 1D).

Students are not expected to reproduce derivations.

Hot dense materials emit a continuous distribution of thermal radiation (e.g., blackbody radiation). When light from a hot gas is examined with a spectroscope, however, a non-continuous emission spectrum is observed. Similarly, when light passes through a gas at low pressure a pattern of dark lines is produced (Figure 15.17 *Pearson Physics*, p. 772).

Bohr posited that an electron moves in a circular orbit around the proton, where the Coulomb force provides the centripetal force of attraction. Based on classical physics, the orbiting electron should continuously emit radiation, losing energy and eventually spiralling into the nucleus. Bohr proposed that only certain orbits are stable and that radiation is emitted only when an electron moves from one orbit to another. The energy for each orbit can be calculated using

$$E_n = \frac{-13.6}{n^2} \text{ eV}, \text{ where } n \text{ is the energy level.}$$

Students should

- describe how the Bohr atomic model explains emission and absorption spectra,
- calculate specific energy levels using $E_n = \frac{-13.6}{n^2} \text{ eV}$ and the difference between any two energy levels of the Bohr atom using $\Delta E = E_{\text{higher}} - E_{\text{lower}}$, and
- calculate the energy of emitted and absorbed photons.

Students should use the Bohr atomic model to explain fluorescence and phosphorescence.

Continued

Photon Momentum and Wave Properties of Matter

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Connect the photoelectric effect to the work of Compton with X-ray scattering.

Students may

- Using a spectroscope, compare the continuous spectrum of natural light with emission spectra for gas discharge tubes in a high voltage power supply (emission spectra may also be sourced online).

Consolidation

Students may

- Differentiate between fluorescence and phosphorescence using a graphic organizer.
- Add to the infographic describing the historical development of quantum theory introduced on page 155.

Extension

Students may

- Research and identify the atomic spectra of different stars and determine their chemical composition from the spectra.
- If an electron orbiting the nucleus of a hydrogen atom falls from a higher energy level back to the second energy level, and a photon with frequency of 6.15×10^{14} Hz is emitted, determine the original energy level of the electron.

Resources and Notes

Authorized

Pearson Physics Level 30 (TR)

- Unit VII: Chapter 14 pp. 15-19
- Unit VIII: Chapter 15 pp. 20-28

Pearson Physics (SR)

- pp. 721-725, 771-781

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Compton effect (websites and videos)
- Bohr model of the atom (websites and videos)
- Fluorescence and phosphorescence (websites)

Photon Momentum and Wave Properties of Matter

Outcomes

Students will be expected to

59.0 summarize the evidence for the wave and particle models of light
[GCO 3]

60.0 explain the de Broglie hypothesis
[GCO 3]

Focus for Learning

The work of Planck, Einstein, and Compton clearly showed that light exhibits particle-like properties in certain contexts. This is in contrast to the wave-like properties observed by Huygens, Young, and others. Scientists have accepted this dichotomy and recognize the wave-particle duality of light.

Students should summarize evidence supporting both the wave and particle model of light:

Phenomenon	Wave Model	Particle Model
Reflection	x	x
Refraction	x	x
Interference	x	
Diffraction	x	
Blackbody radiation		x
Photoelectric effect		x
Compton effect		x
Line spectra		x

If light can sometimes act like particles, then why can't particles sometimes act like waves? Although physicists accepted the wave-particle duality of light, there were still difficulties with describing particles, such as electrons, in the quantum world. De Broglie suggested that like light, classical particles also have wave-like properties. He hypothesized that a particle with momentum p has a

wavelength of $\lambda = \frac{h}{p} = \frac{h}{mv}$. De Broglie's hypothesis was later

experimentally confirmed by Davisson and Germer.

Students should

- solve problems using de Broglie's wave equation;
- calculate de Broglie wavelengths for real world-sized objects (e.g., basketball) to develop an understanding of why we do not see the wave nature of objects of that scale; and
- explore the application of matter waves to the functioning of an electron microscope.

Continued

Photon Momentum and Wave Properties of Matter

Sample Teaching and Assessment Strategies**Connection**

Students may

- Explain what is meant by the wave-particle duality of light.
- Compare the behaviour of long wavelength of light to shorter wavelengths.
- Explore the feature The Electron Microscope (*Pearson Physics*, p. 727) as an application of matter waves.

Consolidation

Students may

- Add to the infographic describing the historical development of quantum theory introduced on page 155.

Resources and Notes**Authorized**

Pearson Physics Level 20 (TR)

- Unit VII: Chapter 14 pp. 19-24

Pearson Physics (SR)

- pp. 726-733

Suggested

Resource Links: www.k12pl.nl.ca/curr/10-12/science/science-courses/physics-3204/resource-links.html

- Wave-particle duality (websites and videos)
- De Broglie's hypothesis (websites and videos)

Photon Momentum and Wave Properties of Matter

Outcomes

Students will be expected to

55.0 explain the Compton effect using the laws of mechanics, the conservation of momentum, and the nature of light
[GCO 3]

56.0 explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts
[GCO 3]

57.0 explain the relationship between the energy levels in Bohr's model, the energy difference between the levels, and the energy of the emitted photons
[GCO 3]

60.0 explain the de Broglie hypothesis
[GCO 3]

Focus for Learning

Sample Performance Indicators

1. What is the momentum of a photon with wavelength 4.51×10^{-11} m?
2. What is the change in energy when an electron drops from $n = 4$ to $n = 2$?
3. An electron in a hydrogen atom has -0.544 eV of energy. What energy level is this electron in?
4. Calculate the wavelength of the photon emitted when an electron in a hydrogen atom moves from the fifth to the second energy level.
5. Calculate the speed of an electron having the same momentum as a photon with a wavelength of 8.0×10^{-10} m.
6. What is the de Broglie wavelength of an electron that has a velocity of 4.8×10^6 m/s?
7. Calculate the de Broglie wavelength of a 1.0×10^3 kg car moving at 25 m/s.

Photon Momentum and Wave Properties of Matter

Sample Teaching and Assessment Strategies**Resources and Notes****Authorized***Pearson Physics Level 30 (TR)*

- Unit VII: Chapter 14 pp. 15-24
- Unit VIII: Chapter 15 pp. 20-28

Pearson Physics (SR)

- pp. 721-733, 771-781

Appendix A: Scientific Conventions

Scientific Conventions

Scientific information should be communicated according to accepted scientific conventions. These conventions include significant figures, formulas, units, and data (graphs, diagrams, tables). The Department of Education and Early Childhood Development follows the conventions below for public exams.

Significant Figures

Any number used in a calculation should contain only figures that are considered reliable; otherwise, time and effort are wasted. Figures that are considered reliable are called significant figures. Scientific calculations generally involve numbers representing actual measurements. In a measurement, significant figures in a number consist of:

Figures (digits) definitely known + one estimated figure (digit)

They are often expressed as “all of the digits known for certain plus one that is uncertain”.

Significant Figure Rules

1. All non-zero digits are significant.
2. Zero rules
 - Trailing zeros (i.e., at the end to the right) of a measurement may or may not be significant:
 - If it represents a measured quantity, it is significant (e.g., 25.0 cm - the zero is significant; the decimal is clearly indicated).
 - If immediately to the left of the decimal, it is not significant (e.g., 250 cm or 2500 cm - zeros are not significant; both have 2 significant digits as there is uncertainty whether zeros are measured values).
 - If the trailing zeros in 250 cm and 2500 cm are significant, the measurements must be written in scientific notation (e.g., 2.50×10^2 cm or 2.500×10^3 cm - zeros are significant).
Note: Scientific notation is not part of the K-12 mathematics program.
 - A zero, between two non-zero digits in a measurement, is significant (e.g., 9.04 cm - the zero is significant).
 - Leading zeros (i.e., at the beginning to the left) are never significant (i.e., they do not represent a measured quantity), they merely locate the decimal point (e.g., 0.46 cm and 0.07 kg - the zeros are not significant).

3. Rounding with Significant Figures

In reporting a calculated measured quantity, rounding an answer to the correct number of significant figures is important if the calculated measurement is to have any meaning. The rules for rounding are listed below.

- If the figure to be dropped is less than 5, eliminate it:
 - rounding 39.949 L to three significant figures results in 39.9 L
 - rounding 40.0 g to two significant figures results in 4.0×10^1 g
- If the figure to be dropped is greater than or equal to 5, eliminate it and raise the preceding figure by 1:
 - rounding 39.949 L to four significant figures results in 39.95 L
 - rounding 39.949 L to two significant figures results in 4.0×10^1 L

4. Multiplying and Dividing with Significant Figures

In determining the number of significant figures in a measurement that is calculated by multiplying or dividing, the measurement with the least number of significant figures should be identified. The final calculated measurement should contain the same number of significant figures as the measurement with the least number of significant figures.

$$2.1 \text{ cm} \times 3.24 \text{ cm} = 6.8 \text{ cm}^2$$

Since 2.1 cm contains two significant figures and 3.24 contains three significant figures, the calculated measurement should contain no more than two significant figures.

5. Adding and Subtracting with Significant Figures

In determining the number of significant figures when adding or subtracting, the final calculation should be rounded to the same precision as the least precise measurement.

$$42.56 \text{ g} + 39.460 \text{ g} + 4.1 \text{ g} = 86.1 \text{ g}$$

Since 4.1 g has only one decimal place, the calculated measurement must be rounded to one decimal place.

6. Performing a Series of Calculations with Mixed Operations

When a series of calculations is performed, it is important to remember that multiplication/division and addition/subtraction are governed by separate significant figure rules. Rounding only occurs at the last step.

When calculations involve both of these types of operations, the rules must be followed in the same order as the operations. Rounding still only occurs at the last step of the calculation.

$$\frac{(0.428 + 0.0804)}{0.009800}$$

The addition is first, $0.428 + 0.0804 = 0.5084$. Following the rules for addition/subtraction, the answer should have three significant figures, but rounding is the last step. Therefore, 0.5084 is used in the next step, $0.5084 \div 0.009800 = 51.87755$. Following the rules for multiplication/division, the answer should have four significant figures (but rounding is the last step). The sum of the numerator has three significant figures, and the denominator has four, so the final answer is rounded to three significant figures, 51.9.

In problems requiring multiple calculations (e.g., calculating final velocity and then using that value to calculate time), it is recommended that rounding only occur in the final calculation. Also, to improve accuracy and consistency, an extra digit should be carried in all intermediate calculations. Students may find it helpful to write the extra digit as a subscript (e.g., 39.5_4 [3 significant figures + 1 extra]).

7. Calculating with Exact Numbers

Sometimes numbers used in a calculation are exact rather than approximate. This is true when using defined quantities, including many conversion factors, and when using pure numbers. Pure or defined numbers do not affect the accuracy of a calculation. You may think of them as having an infinite number of significant figures. Calculating with exact numbers is important when dealing with conversions or calculating molar ratios in chemistry.

8. Scientific Constants

Treat scientific constants as significant digits because they are rounded values (i.e., actual measured or defined values have many decimal places [e.g., the speed of light constant, 3.00×10^8 m/s, is a rounded value based on the defined value, 299 792 458 m/s]).

9. Significant Figures in Logarithms

When determining the number of significant figures from a logarithm function, only the digits to the right of the decimal should be counted as significant figures.

- What is the pH of a sample of orange juice that has 2.5×10^{-4} mol/L hydronium ions?
The measurement 2.5×10^{-4} mol/L has two significant figures. The power of ten indicates where the decimal is located (i.e. 0.00025). The pH of the sample is $-\log(2.5 \times 10^{-4}) = 3.602\ 059$. The digit to the left of the decimal is derived from the power of ten, therefore, it is not significant. Only two digits to the right of the decimal are significant. The answer should be recorded as 3.60.
- What is the hydronium ion concentration of orange juice with pH = 2.25?
The pH value, 2.25, has two significant figures. The hydronium ion concentration is equal to the antilogs of -2.25. This value is 0.0056234 mol/L, which, when rounded to two significant figures, becomes 0.0056 mol/L or 5.6×10^{-3} mol/L.

Formulas and Units

A constructed response question that requires numerical calculations often uses formulas or equations as the starting point to its solution. Proper use of formulas and units in science indicates a thorough understanding of the logic to solve a problem. For any solution that requires the mathematical manipulation of a formula, the formula should be stated at the beginning, followed by workings that clearly indicate the mathematical computations necessary to find the solution.

For most cases in science, a SI unit follows a measured value because it describes the value. Three exceptions to this are pH, equilibrium constants, and index of refraction. The final answer of a solution for a constructed response question that requires the mathematical manipulation of a formula always has a unit with the value. The workings of a solution that lead to the final answer do not have to show units.

Data

Data is generally presented in the form of graphs, tables, and drawings. When these formats are used several scientific conventions should be followed.

Graphs

Graphs represent relationships between numerical information in a pictorial form. Two kinds of graphs are commonly used in science courses in Newfoundland and Labrador:

- Line graph
 - used to display the relationship between continuous data
 - demonstrates a progression of values or shows how one variable changes in relation to another variable (e.g., growth of a child with age)

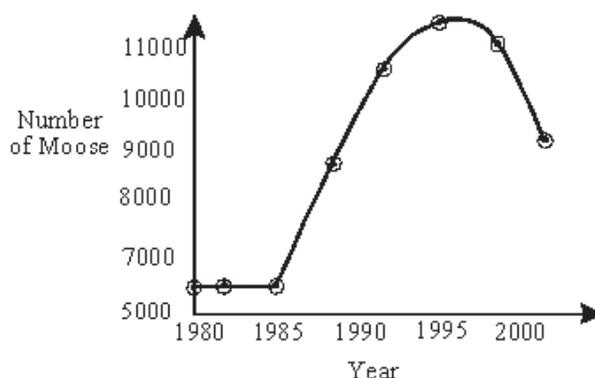
Note: When equations are graphed, a line or curve of best-fit must be drawn.

- Bar graph
 - used to display discrete or discontinuous data
 - consists of parallel bars whose lengths are proportional to quantities given in a set of data. The items compared are plotted along the horizontal axis and appropriate measurement is plotted along the vertical axis (e.g., populations of different types of protists in a lake).

Graphing Rules:

1. The graph must have a title. The title represents the relationship between the two variables.
2. The independent variable is on the horizontal x-axis.
3. The dependent variable is on the vertical y-axis.
4. Each axis is specifically labelled with units (if applicable) according to the variable it represents and values are provided with equal increments. The scale does not have to be the same on both axes, but the scales must accommodate the ranges of the two variables (i.e., the graph line or series of bars must fill $\geq 75\%$ of the available space).
Note: It is not necessary that both axes start at zero. See example below.
5. When data are plotted, a circle should be placed around each point to indicate a degree of error. The graph may show exact numbers or a general relationship. A best-fit line or curve must be used in line and scatter graphs.
6. A legend may be used to identify individual lines on a multi-line graph.

Moose Population in Newfoundland and Labrador (1980 - 2000)

**Tables**

Tables represent numerical or textual information in an organized format. They show how different variables are related to one another by clearly labelling data in a horizontal or vertical format. As with graphs, tables must have a title that represents the relationship between the variables.

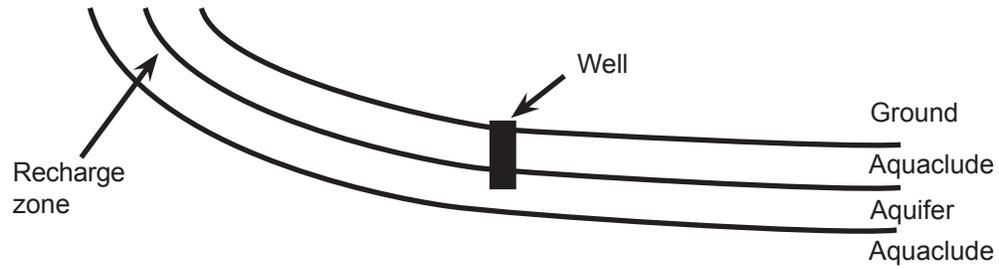
Moose Populations in Newfoundland and Labrador (1980 - 2000)

Year	Number of Moose
1980	5789
1985	6057
1990	8823
1995	11 156
2000	9315

Drawings

Biological drawings that indicate a scale are not required. Diagrams, however, may often be used to aid explanations. These should be clear and properly labelled to indicate important aspects of the diagram.

Geological Conditions Necessary for an Artesian Well



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