This document represents an updating of the 1996 IRP. This updating has been undertaken for the purpose of

- clarifying the Prescribed Learning Outcomes
- introducing Suggested Achievement Indicators
- addressing content overload

Resources previously recommended for the 1996 version of the curriculum, where still valid, continue to support this updated IRP. (See the Learning Resources section in this IRP for additional information.)

# Physics 11 and 12

*Integrated Resource Package 2006*

British Columbia
The Best Place on Earth
Ministry of Education

IRP 142

**Library and Archives Canada Cataloguing in Publication Data**
Main entry under title:
Physics 11 and 12 : integrated resource package 2006.

Also available on the Internet.
Includes bibliographical references: p.
ISBN 0-7726-5524-3

1. Physics – Study and teaching (Secondary) – British Columbia.
2. Education, Secondary – Curricula – British Columbia. I. British Columbia.
Ministry of Education.

QC20.815.C3P49 2006 530.071'2711 C2006-960053-8

## ACKNOWLEDGMENTS



## PREFACE



## INTRODUCTION TO PHYSICS 11 AND 12



## CONSIDERATIONS FOR PROGRAM DELIVERY



## PRESCRIBED LEARNING OUTCOMES



## STUDENT ACHIEVEMENT



## LEARNING RESOURCES

This document has been updated from the 1996 IRP to include suggested achievement indicators, a more clear and succinct set of prescribed learning outcomes, a snapshot of the course's key elements, and other minor refinements, while maintaining the original intent and essence of the 1996 curricular content.

Many people contributed their expertise to the Physics 11 and 12 IRP. The Project Manager (2005-2006) was Mr. Waël Afifi of the Ministry of Education, working with other ministry personnel and our partners in education. We would like to thank all who participated in this process, including the teams of educators who developed the 1996 Physics 11 and 12 IRP, and the following individuals who contributed to the 2005-2006 updating of this document:

| | |
|---|---|
| Jim Axford | School District No. 68 (Nanaimo) |
| Darrel Barber | School District No. 37 (Delta) |
| Matthew Bourget | School District No. 71 (Comox) |
| Gerrit Keizer | Simon Fraser University |
| Anne Laite | School District No. 46 (Sunshine Coast) |
| Jeanette Laursoo | Independent School (Mulgrave School, West Vancouver) |
| Barbara McKinley | School District No. 44 (North Vancouver) |
| Megan Ryan | School District No. 35 (Langley) |
| GT Publishing Services, Ltd. | project co-ordination, writing, and editing |

This Integrated Resource Package (IRP) provides basic information teachers will require in order to implement Physics 11 and 12. This document supersedes the *Physics 11 and 12 Integrated Resource Package* (1996).

The information contained in this document is also available on the Internet at www.bced.gov.bc.ca/irp/irp.htm

The following paragraphs provide brief descriptions of the components of the IRP.

### Introduction

The Introduction provides general information about Physics 11 and 12, including special features and requirements.

Included in this section are

- a rationale for teaching Physics 11 and 12 in BC schools
- information about graduation program requirements and provincial examinations
- listings of each course's curriculum organizers and suborganizers – groupings for prescribed learning outcomes that share a common focus
- suggested time allotments for each course

### Considerations for Program Delivery

This section of the IRP contains additional information to help educators develop their school practices and plan their program delivery to meet the needs of all learners.

### Prescribed Learning Outcomes

This section contains the *prescribed learning outcomes*, the legally required content standards for the provincial education system. The learning outcomes define the required knowledge, skills, and attitudes for each subject. They are statements of what students are expected to know and be able to do by the end of the course.

### Student Achievement

This section of the IRP contains information about classroom assessment and measuring student achievement, including sets of specific achievement indicators for each prescribed learning outcome. Achievement indicators are statements that describe what students should be able to do in order to demonstrate that they fully meet the expectations set out by the prescribed learning outcomes. Achievement indicators are not mandatory; they are provided to assist in the assessment of how well students achieve the prescribed learning outcomes.

Also included in this section are key elements – descriptions of content that help determine the intended depth and breadth of the prescribed learning outcomes.

### Learning Resources

This section contains general information on learning resources, and provides a link to titles, descriptions, and ordering information for the recommended learning resources in the Physics 11 and 12 Grade Collections.

# INTRODUCTION

*Physics 11 and 12*

This Integrated Resource Package (IRP) sets out the provincially prescribed curriculum for Physics 11 and 12. The development of this IRP has been guided by the principles of learning:

- Learning requires the active participation of the student.
- People learn in a variety of ways and at different rates.
- Learning is both an individual and a group process.

In addition to these three principles, this document recognizes that British Columbia's schools include young people of varied backgrounds, interests, abilities, and needs. Wherever appropriate for this curriculum, ways to meet these needs and to ensure equity and access for all learners have been integrated as much as possible into the learning outcomes and achievement indicators.

This document represents an updating of the 1996 IRP. This updating has been undertaken for the purpose of

- clarifying the prescribed learning outcomes
- introducing suggested achievement indicators
- addressing content overload

Resources previously recommended for the 1996 version of the curriculum, where still valid, continue to support this updated IRP. (See the Learning Resources section later in this IRP for additional information.)

Physics 11 and 12, in draft form, was available for public review and response from December, 2005 to January, 2006. Feedback from educators, students, parents, and other educational partners informed the development of this updated IRP.

## Rationale

The science curriculum of British Columbia provides a foundation for the scientific literacy of citizens, for the development of a highly skilled and adaptable work force, and for the development of new technologies. It is a foundation on which teachers can develop a science program that provides a comprehensive set of knowledge, skills, and experiences related to science.

School science programs that are planned to develop scientifically literate students provide experiences that

- help students become flexible and adaptable rather than focussing on acquiring specialized knowledge
- develop the capacity to think critically
- call for a wide range of knowledge, methods, and approaches that enable students to analyse personal and societal issues critically
- encourage students to examine the impact of scientific knowledge on their lives, society, and the environment
- develop a positive attitude toward science
- cultivate students' appreciation of the scientific endeavour and their potential to contribute to it

The science curricula of British Columbia provide a framework of opportunities for students to become scientifically literate by

- examining basic concepts, principles, laws, and theories through scientific inquiry
- actively gaining knowledge, skills, and attitudes that provide the basis for sound and ethical problem solving and decision making
- developing an understanding of the place of science in society and history and its relationship to other disciplines
- making informed and responsible decisions about themselves, their homes, workplaces, and the global community

## Requirements and Graduation Credits

Physics 11 and 12 are two of the courses available for students to satisfy the Grade 11-12 Graduation Program science requirement.

Physics 11 and 12 are each designated as four-credit courses, and must be reported as such to the Ministry of Education for transcript purposes. Letter grades and percentages must be reported for these courses. It is not possible to obtain partial credit for these courses.

The course codes for Physics 11 and 12 are PH 11 and PH 12. These courses are also available in French (Physique 11, Physique 12; course codes PHYSF 11, PHYSF 12).

## Graduation Program Examination

Physics 12 has an optional Graduation Program examination, worth 40% of the final course mark for students who choose to write it. Although students are not required to take this exam to receive credit for the course, they should be advised that some post-secondary institutions require Grade 12 exams to meet entrance requirements, and that writing Grade 12 exams also provides opportunities for provincial scholarships.

> For more information, refer to the Ministry of Education examinations web site: www.bced.gov.bc.ca/exams/

## Curriculum Organizers

A curriculum organizer consists of a set of prescribed learning outcomes that share a common focus. The prescribed learning outcomes for Physics 11 and 12 are grouped under the following curriculum organizers.

Note that the ordering of these organizers is not intended to imply an order of instruction.

| Physics 11 | Physics 12 |
|---|---|
| • Skills, Methods, and Nature of Physics<br>• Wave Motion and Geometrical Optics<br>• Kinematics<br>• Forces<br>• Newton's Laws<br>• Momentum<br>• Energy<br>• Special Relativity<br>• Nuclear Fission and Fusion | • Experiments and Graphical Methods<br>• Vectors<br>• Kinematics<br>• Dynamics<br>• Work, Energy, and Power<br>• Momentum<br>• Equilibrium<br>• Circular Motion<br>• Gravitation<br>• Electrostatics<br>• Electric Circuits<br>• Electromagnetism |

## Suggested Timeframe

Provincial curricula are developed in accordance with the amount of instructional time recommended by the Ministry of Education for each subject area. Teachers may choose to combine various curricula to enable students to integrate ideas and make meaningful connections.

Physics 11 and 12 each require approximately 90–110 hours of instructional time. Although a four-credit course is typically equivalent to 120 hours, this timeframe allows for flexibility to address local needs. The Student Achievement section of this IRP provides a suggested breakdown of this suggested time allotment by curriculum organizer.

# Considerations for Program Delivery

*Physics 11 and 12*

This section of the IRP contains additional information to help educators develop their school practices and plan their program delivery to meet the needs of all learners. Included in this section is information about

- Alternative Delivery policy
- addressing local contexts
- involving parents and guardians
- course requirements respecting beliefs
- safety considerations
- confidentiality
- inclusion, equity, and accessibility for all learners
- working with the school and community
- working with the Aboriginal community
- information and communications technology
- copyright and responsibility

## Alternative Delivery Policy

The Alternative Delivery policy does not apply to Physics 11 and 12.

The Alternative Delivery policy outlines how students, and their parents or guardians, in consultation with their local school authority, may choose means other than instruction by a teacher within the regular classroom setting for addressing prescribed learning outcomes contained in the Health curriculum organizer of the following curriculum documents:

- Health and Career Education K to 7, and Personal Planning K to 7 Personal Development curriculum organizer (until September 2008)
- Health and Career Education 8 and 9
- Planning 10

The policy recognizes the family as the primary educator in the development of children's attitudes, standards, and values, but the policy still requires that all prescribed learning outcomes be addressed and assessed in the agreed-upon alternative manner of delivery.

It is important to note the significance of the term "alternative delivery" as it relates to the Alternative Delivery policy. The policy does not permit schools to omit addressing or assessing any of the prescribed learning outcomes within the health and career education curriculum. Neither does it allow students to be excused from meeting any learning outcomes related to health. It is expected that students who arrange for alternative delivery will address the health-related learning outcomes and will be able to demonstrate their understanding of these learning outcomes.

> For more information about policy relating to alternative delivery, refer to www.bced.gov.bc.ca/policy/

## Addressing Local Contexts

There is some flexibility in the Physics 11 and 12 curriculum, providing opportunities for individual teacher and student choice in the selection of topics to meet learning outcomes. This flexibility enables educators to plan their programs by using topics and examples that are relevant to their local context and to the particular interests of their students. When selecting topics it may be appropriate to incorporate student input.

## Involving Parents and Guardians

The family is the primary educator in the development of students' attitudes and values. The school plays a supportive role by focussing on the prescribed learning outcomes in the Physics 11 and 12 curriculum. Parents and guardians can support, enrich, and extend the curriculum at home.

It is highly recommended that schools inform parents and guardians about the Physics 11 and 12 curriculum, and teachers (along with school and district administrators) may choose to do so by

- informing parents/guardians and students of the prescribed learning outcomes for the subject by sending home class letters, providing an overview during parent-teacher interviews, etc.
- responding to parent and guardian requests to discuss course unit plans, learning resources, etc.

## Course Requirements Respecting Beliefs

For many students and teachers, the study of some science concepts may lead to issues and questions that go beyond the immediate scope of curriculum (e.g., science is used to meet many industrial requirements, but industrial decision makers must consider factors other than scientific feasibility before adopting a particular process). The technological application of science in areas such as genetic engineering, human reproduction, and medical technology raises questions of ethics and values. Because these social questions arise, in part, from capabilities that science makes possible, they should be addressed. It must be made clear to students, however, that science only provides the background for what is hoped will be informed personal and social decisions. Teachers must handle these questions objectively and with sensitivity.

Reconciling scientific discoveries (for example, in age dating) and religious faith poses a particular challenge for some students. While respecting the personal beliefs of students, teachers should be careful to distinguish between knowledge based on the application of scientific methods, and religious teachings and associated beliefs such as creationism, theory of divine creation, or intelligent design theory.

### SAFETY CONSIDERATIONS

Science education is an activity-based process that provides an exciting method of teaching and learning. However, experiments and demonstrations may involve inherent risks for both the teacher and the student.

Safety guidelines must be discussed with students. These safety guidelines must support and encourage the investigative approach generally and laboratory instruction specifically, while at the same time promoting safety in the classroom and laboratory. Encouraging a positive safety attitude is a responsibility shared among the board, school administrators, teachers, and students in every school district. The co-operation of all these groups helps develop a strong safety consciousness both inside and outside our schools.

Field work and field trips require special vigilance with respect to traffic and road safety, safe practices in study areas and when obtaining samples, and an awareness of changes in weather.

Another important aspect of in-school safety is the Workplace Hazardous Materials Information Systems (WHMIS). Through labelling, material safety data sheets, and education and training, WHMIS is designed to ensure that those using hazardous materials have sufficient information to handle them safely. Each school district should have an individual trained in WHMIS who can work with teachers to establish safe, well-ventilated classroom and laboratory working conditions.

To assist teachers in providing a safe science-learning environment, the Ministry of Education publishes the *Science Safety Resource Manual*, which has been distributed to every school.

> The *Science Safety Resource Manua*l is available online at
> www.bced.gov.bc.ca/irp/resdocs/scisafety.htm

### CONFIDENTIALITY

The *Freedom of Information and Protection of Privacy Act* (FOIPPA) applies to students, to school district employees, and to all curricula. Teachers, administrators, and district staff should consider the following:

- Be aware of district and school guidelines regarding the provisions of FOIPPA and how it applies to all subjects, including Physics 11 and 12.
- Do not use students' Personal Education Numbers (PEN) on any assignments that students wish to keep confidential.
- Ensure students are aware that if they disclose personal information that indicates they are at risk for harm, then that information cannot be kept confidential.
- Inform students of their rights under FOIPPA, especially the right to have access to their own personal information in their school records. Inform parents of their rights to access their children's school records.
- Minimize the type and amount of personal information collected, and ensure that it is used only for purposes that relate directly to the reason for which it is collected.

- Inform students that they will be the only ones recording personal information about themselves unless they, or their parents, have consented to teachers collecting that information from other people (including parents).
- Provide students and their parents with the reason(s) they are being asked to provide personal information in the context of the Physics 11 and 12 curriculum.
- Inform students and their parents that they can ask the school to correct or annotate any of the personal information held by the school, in accordance with Section 29 of FOIPPA.
- Ensure students are aware that their parents may have access to the schoolwork they create only insofar as it pertains to students' progress.
- Ensure that any information used in assessing students' progress is up-to-date, accurate, and complete.

For more information about confidentiality, refer to www.mser.gov.bc.ca/FOI_POP/index.htm

## INCLUSION, EQUITY, AND ACCESSIBILITY FOR ALL LEARNERS

British Columbia's schools include students of varied backgrounds, interests, and abilities. The Kindergarten to Grade 12 school system focuses on meeting the needs of all students. When selecting specific topics, activities, and resources to support the implementation of Physics 11 and 12, teachers are encouraged to ensure that these choices support inclusion, equity, and accessibility for all students. In particular, teachers should ensure that classroom instruction, assessment, and resources reflect sensitivity to diversity and incorporate positive role portrayals, relevant issues, and themes such as inclusion, respect, and acceptance.

Government policy supports the principles of integration and inclusion of students for whom English is a second language and of students with special needs. Most of the prescribed learning outcomes and suggested achievement indicators in this IRP can be met by all students, including those with special needs and/or ESL needs. Some strategies may require adaptations to ensure that those with special and/or ESL needs can successfully achieve the learning outcomes. Where necessary, modifications can be made to the prescribed learning outcomes for students with Individual Education Plans.

For more information about resources and support for students with special needs, refer to www.bced.gov.bc.ca/specialed/

For more information about resources and support for ESL students, refer to www.bced.gov.bc.ca/esl/

## WORKING WITH THE SCHOOL AND COMMUNITY

This curriculum addresses a wide range of skills and understandings that students are developing in other areas of their lives. It is important to recognize that learning related to this curriculum extends beyond the science classroom.

School and district-wide programs support and extend learning in Physics 11 and 12. Community organizations may also support the curriculum with locally developed learning resources, guest speakers, workshops, and field studies. Teachers may wish to draw on the expertise of these community organizations and members.

## WORKING WITH THE ABORIGINAL COMMUNITY

The Ministry of Education is dedicated to ensuring that the cultures and contributions of Aboriginal peoples in BC are reflected in all provincial curricula. To address these topics in the classroom in a way that is accurate and that respectfully reflects Aboriginal concepts of teaching and learning, teachers are strongly encouraged to seek the advice and support of local Aboriginal communities. Aboriginal communities are diverse in terms of language, culture, and available resources, and each community will have its own unique protocol to gain support for integration of local knowledge and expertise. To begin discussion of possible instructional and assessment activities, teachers should first contact Aboriginal education co-ordinators, teachers, support workers, and counsellors in their district who will be able to facilitate the identification of local resources and contacts such as elders, chiefs, tribal or band councils, Aboriginal cultural centres, Aboriginal Friendship Centres, and Métis or Inuit organizations.

In addition, teachers may wish to consult the various Ministry of Education publications available, including the "Planning Your Program" section of the resource, *Shared Learnings*. This resource was developed to help all teachers provide students with knowledge of, and opportunities to share experiences with, Aboriginal peoples in BC.

For more information about these documents, consult the Aboriginal Education web site: www.bced.gov.bc.ca/abed/welcome.htm

## Information and Communications Technology

The study of information and communications technology is increasingly important in our society. Students need to be able to acquire and analyse information, to reason and communicate, to make informed decisions, and to understand and use information and communications technology for a variety of purposes. Development of these skills is important for students in their education, their future careers, and their everyday lives.

Literacy in the area of information and communications technology can be defined as the ability to obtain and share knowledge through investigation, study, instruction, or transmission of information by means of media technology. Becoming literate in this area involves finding, gathering, assessing, and communicating information using electronic means, as well as developing the knowledge and skills to use and solve problems effectively with the technology. Literacy also involves a critical examination and understanding of the ethical and social issues related to the use of information and communications technology. When planning for instruction and assessment in Physics 11 and 12, teachers should provides opportunities for students to develop literacy in relation to information and communications technology sources, and to reflect critically on the role of these technologies in society.

## Copyright and Responsibility

Copyright is the legal protection of literary, dramatic, artistic, and musical works; sound recordings; performances; and communications signals. Copyright provides creators with the legal right to be paid for their work and the right to say how their work is to be used. The law permits certain exceptions for schools (i.e., specific things permitted) but these are very limited, such as copying for private study or research. The copyright law determines how resources can be used in the classroom and by students at home.

In order to respect copyright it is necessary to understand the law. It is unlawful to do the following, unless permission has been given by a copyright owner:

- photocopy copyrighted material to avoid purchasing the original resource for any reason
- photocopy or perform copyrighted material beyond a very small part – in some cases the copyright law considers it "fair" to copy whole works, such as an article in a journal or a photograph, for purposes of research and private study, criticism, and review
- show recorded television or radio programs to students in the classroom unless these are cleared for copyright for educational use (there are exceptions such as for news and news commentary taped within one year of broadcast that by law have record-keeping requirements – see the web site at the end of this section for more details)
- photocopy print music, workbooks, instructional materials, instruction manuals, teacher guides, and commercially available tests and examinations
- show videorecordings at schools that are not cleared for public performance
- perform music or do performances of copyrighted material for entertainment (i.e., for purposes other than a specific educational objective)
- copy work from the Internet without an express message that the work can be copied

Permission from or on behalf of the copyright owner must be given in writing. Permission may also be given to copy or use all or some portion of copyrighted work through a licence or agreement. Many creators, publishers, and producers have formed groups or "collectives" to negotiate royalty payments and copying conditions for educational institutions. It is important to know what licences are in place and how these affect the activities schools are involved in. Some licences may also require royalty payments that are determined by the quantity of photocopying or the length of performances. In these cases, it is important to assess the educational value and merits of copying or performing certain works to protect the school's financial exposure (i.e., only copy or use that portion that is absolutely necessary to meet an educational objective).

It is important for education professionals, parents, and students to respect the value of original thinking and the importance of not plagiarizing the work of others. The works of others should not be used without their permission.

For more information about copyright, refer to www.cmec.ca/copyright/indexe.stm

# Prescribed Learning Outcomes

*Physics 11 and 12*

*Prescribed learning outcomes* are content standards for the provincial education system; they are the prescribed curriculum. Clearly stated and expressed in measurable and observable terms, learning outcomes set out the required knowledge, skills, and attitudes – what students are expected to know and be able to do – by the end of the specified course.

Schools have the responsibility to ensure that all prescribed learning outcomes in this curriculum are met; however, schools have flexibility in determining how delivery of the curriculum can best take place.

It is expected that student achievement will vary in relation to the learning outcomes. Evaluation, reporting, and student placement with respect to these outcomes are dependent on the professional judgment and experience of teachers, guided by provincial policy.

Prescribed learning outcomes for Physics 11 and 12 are presented by grade and by curriculum organizer, and are coded alphanumerically for ease of reference; however, this arrangement is not intended to imply a required instructional sequence.

## WORDING OF PRESCRIBED LEARNING OUTCOMES

All learning outcomes complete the stem, "It is expected that students will…."

When used in a prescribed learning outcome, the word "including" indicates that any ensuing item **must be addressed**. Lists of items introduced by the word "including" represent a set of minimum requirements associated with the general requirement set out by the outcome. The lists are not necessarily exhaustive, however, and teachers may choose to address additional items that also fall under the general requirement set out by the outcome.

## DOMAINS OF LEARNING

Prescribed learning outcomes in BC curricula identify required learning in relation to one or more of the three domains of learning: cognitive, psychomotor, and affective. The following definitions of the three domains are based on Bloom's taxonomy.

The **cognitive domain** deals with the recall or recognition of knowledge and the development of intellectual abilities. The cognitive domain can be further specified as including three cognitive levels: knowledge, understanding and application, and higher mental processes. These levels are determined by the verb used in the learning outcome, and illustrate how student learning develops over time.

- *Knowledge* includes those behaviours that emphasize the recognition or recall of ideas, material, or phenomena.
- *Understanding and application* represents a comprehension of the literal message contained in a communication, and the ability to apply an appropriate theory, principle, idea, or method to a new situation.
- *Higher mental processes* include analysis, synthesis, and evaluation. The higher mental processes level subsumes both the knowledge and the understanding and application levels.

The **affective domain** concerns attitudes, beliefs, and the spectrum of values and value systems.

The **psychomotor domain** includes those aspects of learning associated with movement and skill demonstration, and integrates the cognitive and affective consequences with physical performances.

Domains of learning and, particularly, cognitive levels, inform the design and development of the Graduation Program examination for Physics 12.

## Prescribed Learning Outcomes: Physics 11

*It is expected that students will:*

### Skills, Methods, and Nature of Physics

A1 describe the nature of physics
A2 apply the skills and methods of physics

### Wave Motion and Geometrical Optics

B1 analyse the behaviour of light and other waves under various conditions, with reference to the properties of waves and using the universal wave equation
B2 use ray diagrams to analyse situations in which light reflects from plane and curved mirrors
B3 analyse situations in which light is refracted

### Kinematics

C1 apply knowledge of the relationships between time, displacement, distance, velocity, and speed to situations involving objects in one dimension
C2 apply knowledge of the relationships between time, velocity, displacement, and acceleration to situations involving objects in one dimension

### Forces

D1 solve problems involving the force of gravity
D2 analyse situations involving the force due to friction
D3 apply Hooke's law to the deformation of materials

### Newton's Laws

E1 solve problems that involve application of Newton's laws of motion in one dimension

### Momentum

F1 apply the concept of momentum in one dimension

### Energy

G1 perform calculations involving work, force, and displacement
G2 solve problems involving different forms of energy
G3 analyse the relationship between work and energy, with reference to the law of conservation of energy
G4 solve problems involving power and efficiency

### Special Relativity

H1 explain the fundamental principles of special relativity

### Nuclear Fission and Fusion

I1 analyse nuclear processes

## Prescribed Learning Outcomes: Physics 12

*It is expected that students will:*

### Experiments and Graphical Methods

A1 conduct appropriate experiments
A2 use graphical methods to analyse results of experiments

### Vectors

B1 perform vector analysis in one or two dimensions

### Kinematics

C1 apply vector analysis to solve practical navigation problems
C2 apply the concepts of motion to various situations where acceleration is constant

### Dynamics

D1 apply Newton's laws of motion to solve problems involving acceleration, gravitational field strength, and friction
D2 apply the concepts of dynamics to analyse one-dimensional or two-dimensional situations

### Work, Energy, and Power

E1 analyse the relationships among work, energy, and power

### Momentum

F1 use knowledge of momentum and impulse to analyse situations in one dimension
F2 use knowledge of momentum and impulse to analyse situations in two dimensions

### Equilibrium

G1 use knowledge of force, torque, and equilibrium to analyse various situations

### Circular Motion

H1 use knowledge of uniform circular motion to analyse various situations

### Gravitation

I1 analyse the gravitational attraction between masses

### Electrostatics

J1 apply Coulomb's law to analyse electric forces
J2 analyse electric fields and their effects on charged objects
J3 calculate electric potential energy and change in electric potential energy
J4 apply the concept of electric potential to analyse situations involving point charges
J5 apply the principles of electrostatics to a variety of situations

### Electric Circuits

K1 apply Ohm's law and Kirchhoff's laws to direct current circuits
K2 relate efficiency to electric power, electric potential difference, current, and resistance

### Electromagnetism

L1 analyse electromagnetism, with reference to magnetic fields and their effects on moving charges
L2 analyse the process of electromagnetic induction

# Student Achievement

*Physics 11 and 12*

This section of the IRP contains information about classroom assessment and student achievement, including specific achievement indicators to assist in the assessment of student achievement in relation to each prescribed learning outcome. Also included in this section are key elements – descriptions of content that help determine the intended depth and breadth of prescribed learning outcomes.

## Classroom Assessment and Evaluation

Assessment is the systematic gathering of information about what students know, are able to do, and are working toward. Assessment evidence can be collected using a wide variety of methods, such as

- observation
- student self-assessments and peer assessments
- quizzes and tests (written, oral, practical)
- samples of student work
- projects and presentations
- oral and written reports
- journals and learning logs
- performance reviews
- portfolio assessments

Assessment of student performance is based on the information collected through assessment activities. Teachers use their insight, knowledge about learning, and experience with students, along with the specific criteria they establish, to make judgments about student performance in relation to prescribed learning outcomes.

Three major types of assessment can be used in conjunction to support student achievement.

- Assessment **for** learning is assessment for purposes of greater learning achievement.
- Assessment **as** learning is assessment as a process of developing and supporting students' active participation in their own learning.
- Assessment **of** learning is assessment for purposes of providing evidence of achievement for reporting.

### *Assessment for Learning*

Classroom assessment for learning provides ways to engage and encourage students to become involved in their own day-to-day assessment – to acquire the skills of thoughtful self-assessment and to promote their own achievement.

This type of assessment serves to answer the following questions:

- What do students need to learn to be successful?
- What does the evidence of this learning look like?

Assessment for learning is criterion-referenced, in which a student's achievement is compared to established criteria rather than to the performance of other students. Criteria are based on prescribed learning outcomes, as well as on suggested achievement indicators or other learning expectations.

Students benefit most when assessment feedback is provided on a regular, ongoing basis. When assessment is seen as an opportunity to promote learning rather than as a final judgment, it shows students their strengths and suggests how they can develop further. Students can use this information to redirect their efforts, make plans, communicate with others (e.g., peers, teachers, parents) about their growth, and set future learning goals.

Assessment for learning also provides an opportunity for teachers to review what their students are learning and what areas need further attention. This information can be used to inform teaching and create a direct link between assessment and instruction. Using assessment as a way of obtaining feedback on instruction supports student achievement by informing teacher planning and classroom practice.

*Assessment as Learning*

Assessment as learning actively involves students in their own learning processes. With support and guidance from their teacher, students take responsibility for their own learning, constructing meaning for themselves. Through a process of continuous self-assessment, students develop the ability to take stock of what they have already learned, determine what they have not yet learned, and decide how they can best improve their own achievement.

Although assessment as learning is student-driven, teachers can play a key role in facilitating how this assessment takes place. By providing regular opportunities for reflection and self-assessment, teachers can help students develop, practise, and become comfortable with critical analysis of their own learning.

*Assessment of Learning*

Assessment of learning can be addressed through summative assessment, including large-scale assessments and teacher assessments. These summative assessments can occur at the end of the year or at periodic stages in the instructional process.

Large-scale assessments, such as Foundation Skills Assessment (FSA) and Graduation Program exams, gather information on student performance throughout the province and provide information for the development and revision of curriculum. These assessments are used to make judgments about students' achievement in relation to provincial and national standards. There is no large-scale provincial assessment for Physics 11. The large-scale provincial assessment for Physics 12 is the optional graduation program examination, worth 40% of the final course mark for students who choose to write it.

Assessment of learning is also used to inform formal reporting of student achievement.

For Ministry of Education reporting policy, refer to www.bced.gov.bc.ca/policy/policies/student_reporting.htm

| Assessment *for* Learning | Assessment *as* Learning | Assessment *of* Learning |
|---|---|---|
| **Formative assessment is *ongoing in the classroom*** | **Formative assessment is *ongoing in the classroom*** | **Summative assessment occurs *at end of year or at key stages*** |
| • teacher assessment, student self-assessment, and/or student peer assessment<br>• criterion-referenced – criteria based on prescribed learning outcomes identified in the provincial curriculum, reflecting performance in relation to a specific learning task<br>• involves both teacher and student in a process of continual reflection and review about progress<br>• teachers adjust their plans and engage in corrective teaching in response to formative assessment | • self-assessment<br>• provides students with information on their own achievement and prompts them to consider how they can continue to improve their learning<br>• student-determined criteria based on previous learning and personal learning goals<br>• students use assessment information to make adaptations to their learning process and to develop new understandings | • teacher assessment<br>• may be either criterion-referenced (based on prescribed learning outcomes) or norm-referenced (comparing student achievement to that of others)<br>• information on student performance can be shared with parents/guardians, school and district staff, and other education professionals (e.g., for the purposes of curriculum development)<br>• used to make judgments about students' performance in relation to provincial standards |

For more information about assessment for, as, and of learning, refer to the following resource developed by the Western and Northern Canadian Protocol (WNCP): *Rethinking Assessment with Purpose in Mind.*

This resource is available online at www.wncp.ca/

***Criterion-Referenced Assessment and Evaluation***
In criterion-referenced evaluation, a student's performance is compared to established criteria rather than to the performance of other students. Evaluation in relation to prescribed curriculum requires that criteria be established based on the learning outcomes.

Criteria are the basis for evaluating student progress. They identify, in specific terms, the critical aspects of a performance or a product that indicate how well the student is meeting the prescribed learning outcomes. For example, weighted criteria, rating scales, or scoring guides (reference sets) are ways that student performance can be evaluated using criteria.

Wherever possible, students should be involved in setting the assessment criteria. This helps students develop an understanding of what high-quality work or performance looks like.

| Criterion-referenced assessment and evaluation may involve these steps: | |
|---|---|
| **Step 1** | Identify the prescribed learning outcomes and suggested achievement indicators (as articulated in this IRP) that will be used as the basis for assessment. |
| **Step 2** | Establish criteria. When appropriate, involve students in establishing criteria. |
| **Step 3** | Plan learning activities that will help students gain the knowledge, skills, and attitudes outlined in the criteria. |
| **Step 4** | Prior to the learning activity, inform students of the criteria against which their work will be evaluated. |
| **Step 5** | Provide examples of the desired levels of performance. |
| **Step 6** | Conduct the learning activities. |
| **Step 7** | Use appropriate assessment instruments (e.g., rating scale, checklist, scoring guide) and methods (e.g., observation, collection, self-assessment) based on the particular assignment and student. |
| **Step 8** | Review the assessment data and evaluate each student's level of performance or quality of work in relation to criteria. |
| **Step 9** | Where appropriate, provide feedback and/or a letter grade to indicate how well the criteria are met. |
| **Step 10** | Communicate the results of the assessment and evaluation to students and parents/ guardians. |

## KEY ELEMENTS

Key elements provide an overview of content in each curriculum organizer. They can be used to determine the expected depth and breadth of the prescribed learning outcomes.

## ACHIEVEMENT INDICATORS

To support the assessment of provincially prescribed curricula, this IRP includes sets of achievement indicators in relation to each learning outcome.

Achievement indicators, taken together as a set, define the specific level of knowledge acquired, skills applied, or attitudes demonstrated by the student in relation to a corresponding prescribed learning outcome. They describe what evidence to look for to determine whether or not the student has fully met the intent of the learning outcome. Since each achievement indicator defines only one aspect of the corresponding learning outcome, the entire set of achievement indicators should be considered when determining whether students have fully met the learning outcome.

In some cases, achievement indicators may also include suggestions as to the type of task that would provide evidence of having met the learning outcome (e.g., a constructed response such as a list, comparison, analysis, or chart; a product created and presented such as a report, drama presentation, poster, letter, or model; a particular skill demonstrated such as interpreting graphs).

Achievement indicators support the principles of assessment *for* learning, assessment *as* learning, and assessment *of* learning. They provide teachers and parents with tools that can be used to reflect on what students are learning. They also provide students with a means of self-assessment and ways of defining how they can improve their own achievement.

Achievement indicators are not mandatory; they are suggestions only, provided to assist in the assessment of how well students achieve the prescribed learning outcomes.

Achievement indicators may be useful to provincial examination development teams and inform the development of exam items. However, examination questions, item formats, exemplars, rubrics, or scoring guides will not necessarily be limited to the achievement indicators as outlined in the Integrated Resource Packages.

Specifications for provincial examinations are available online at www.bced.gov.bc.ca/exams/specs/

The following pages contain the suggested achievement indicators corresponding to each prescribed learning outcome for the Physics 11 and 12 curriculum. The achievement indicators are arranged by curriculum organizer for each grade; however, this order is not intended to imply a required sequence of instruction and assessment.

# Student Achievement

*Physics 11*

# PHYSICS 11 FORMULAE

### *Wave Motion and Geometrical Optics*

$$\frac{1}{d_i}+\frac{1}{d_o}=\frac{1}{f} \qquad n=\frac{c}{v}$$

$$n_1\sin(\theta_1)=n_2\sin(\theta_2)$$

$$T=\frac{1}{f} \qquad v=f\lambda$$

### *Kinematics*

$$v=\frac{\Delta d}{\Delta t} \qquad a=\frac{\Delta v}{\Delta t}$$

$$d=\bar{v}t$$

$$v=v_0+at \qquad \bar{v}=\frac{v+v_0}{2}$$

$$d=v_0t+\frac{1}{2}at^2 \qquad v^2=v_0^2+2ad$$

### *Forces and Dynamics*

$$F_g=mg \qquad F_g=G\frac{m_1m_2}{r^2}$$

$$F_{fr}=\mu F_N \qquad F=k\Delta x$$

$$F_{net}=ma$$

$$p=mv \qquad \Delta p=F_{net}\Delta t$$

### *Energy*

$$W=Fd \qquad W=\Delta E$$

$$E_p=mgh \qquad E_k=\frac{1}{2}mv^2$$

$$P=\frac{W}{\Delta t}=\frac{\Delta E}{\Delta t}$$

$$efficiency=\frac{W_{out}}{W_{in}}=\frac{P_{out}}{P_{in}}$$

### *Special Relativity*

$$t=\frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} \qquad m=\frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$l=l_0\sqrt{1-\frac{v^2}{c^2}} \qquad v_{total}=\frac{v_1+v_2}{1+\frac{v_1v_2}{c^2}}$$

$$E=mc^2$$

## Key Elements: Skills, Methods, and Nature of Physics

**Estimated Time: integrated with other curriculum organizers**

By the end of this course, students will have developed an understanding of the major areas of study within the field of physics and will be able to appropriately apply the skills and methods of physics.

### *Vocabulary*

coefficient, intercept, inverse, inverse square, linear, slope, square, variable, verify

### *Knowledge*

- characteristics of physics
- major areas of study in physics
- continuing development and refining of physics concepts

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- apply mathematical models to solve a variety of problems
- use appropriate units and metric prefixes

## SKILLS, METHODS, AND NATURE OF PHYSICS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br>*Students who have fully met the prescribed learning outcome are able to:* |
| A1 describe the nature of physics | ❑ distinguish physics from related disciplines<br>❑ describe the major areas of study in physics (e.g., optics, kinematics, fluids, nuclear, quantum)<br>❑ give examples of the continuing development and refining of physics concepts |
| A2 apply the skills and methods of physics | ❑ with teacher support, conduct appropriate experiments<br>❑ systematically gather and organize data from experiments<br>❑ produce and interpret graphs (e.g., slope and intercept)<br>❑ verify relationships (e.g., linear, inverse, square, and inverse square) between variables<br>❑ use models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems<br>❑ use appropriate units and metric prefixes |

## Key Elements: Wave Motion and Geometrical Optics

**Estimated Time: 18–22 hours**

By the end of this course, students will understand reflection and refraction of light and its wave nature.

### *Vocabulary*

amplitude, angle of incidence, angle of reflection, centre and radius of curvature, critical angle, diffraction, Doppler shift, focal length, focal point, frequency, image and object distance, incident ray, index of refraction, interference (superposition principle), normal, period, phase, polarization, principal axis, reflected ray, reflection, refraction, total internal reflection, wavelength, wave speed

### *Knowledge*

- wave properties
- universal wave equation
- wave phenomena and conditions
- visible light portion of the electromagnetic spectrum
- the law of reflection
- images produced by mirrors (plane, converging, and diverging)
- curved mirrors (concave or convex)
- focal length of a concave mirror
- Snell's law
- lens (convex or concave)
- images produced by converging and diverging lenses
- focal length of a convex lens

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- apply models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
- use appropriate units and metric prefixes

## Wave Motion and Geometrical Optics

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
| --- | --- |
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| B1 analyse the behaviour of light and other waves under various conditions, with reference to the properties of waves and using the universal wave equation | ❑ describe the properties associated with waves, including amplitude, frequency, period, wavelength, phase, speed, and types of waves<br>❑ use the universal wave equation to solve problems involving speed, frequency (period), and wavelength<br>❑ describe and give examples of the following wave phenomena and the conditions that produce them:<br>– reflection<br>– refraction<br>– diffraction<br>– interference (superposition principle)<br>– Doppler shift<br>– polarization<br>❑ identify from an appropriate diagram the visible light portion of the electromagnetic spectrum |
| B2 use ray diagrams to analyse situations in which light reflects from plane and curved mirrors<br><br>*Organizer 'Wave Motion and Geometrical Optics' continued on page 31* | ❑ state the law of reflection<br>❑ identify the following on appropriate diagrams:<br>– incident ray<br>– reflected ray<br>– angle of incidence<br>– angle of reflection<br>– normal<br>❑ show how an image is produced by a plane mirror<br>❑ describe the characteristics of an image produced by a plane mirror<br>❑ identify a curved mirror as converging (concave) or diverging (convex)<br>❑ identify the following on appropriate diagrams:<br>– principal axis<br>– centre and radius of curvature<br>– image and object distance<br>– focal point and focal length<br>❑ draw accurate scale diagrams for both concave and convex mirrors to show how an image is produced<br>❑ describe the characteristics of images produced by converging and diverging mirrors<br>❑ conduct an experiment to determine the focal length of a concave mirror |

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *Organizer 'Wave Motion and Geometrical Optics' continued from page 30* | |
| B3 analyse situations in which light is refracted | ❑ identify the following from appropriate diagrams:<br>– incident ray<br>– refracted ray<br>– normal<br>– angle of incidence<br>– angle of reflection<br>❑ use Snell's law to solve a range of problems involving<br>– index of refraction<br>– angle of incidence<br>– angle of reflection<br>❑ define *critical angle* and *total internal reflection*<br>❑ solve problems involving critical angles<br>❑ identify a lens as converging (convex) or diverging (concave)<br>❑ for a lens, identify the following from appropriate diagrams:<br>– principal axis<br>– focal point (primary and secondary)<br>– focal length<br>– image and object distance<br>❑ draw accurate scale diagrams for both convex and concave lenses to show how an image is produced<br>❑ describe the characteristics of images produced by converging and diverging lenses<br>❑ conduct an experiment to determine the focal length of a convex lens |

## Key Elements: Kinematics

**Estimated Time: 18–22 hours**

By the end of this course, students will be able to describe objects in motion in one dimension, using the principles of kinematics.

### *Vocabulary*

acceleration, average velocity, constant acceleration, displacement, final velocity, instantaneous velocity, initial velocity, kinematics, scalar, speed, vector, velocity

### *Knowledge*

- scalar and vector quantities
- distance and displacement
- speed and velocity
- initial velocity, final velocity, average velocity
- instantaneous velocity
- acceleration
- constant acceleration
- projectile motion

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- apply models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
- use appropriate units and metric prefixes
- construct displacement-versus-time graphs
- construct velocity-versus-time graphs

## KINEMATICS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| C1 apply knowledge of the relationships between time, displacement, distance, velocity, and speed to situations involving objects in one dimension | ❑ differentiate between scalar and vector quantities<br>❑ define *distance*, *displacement*, *speed*, and *velocity*<br>❑ construct displacement-versus-time graphs, based on data from various sources (e.g., from an experiment)<br>❑ use a displacement-versus-time graph to determine<br>– displacement and distance<br>– average velocity and speed<br>– instantaneous velocity and speed<br>❑ solve problems involving<br>– displacement<br>– time<br>– average velocity<br>❑ construct velocity-versus-time graphs, based on data from various sources (e.g., from an experiment)<br>❑ use velocity-versus-time graphs to determine<br>– velocity<br>– displacement<br>– average velocity |
| C2 apply knowledge of the relationships between time, velocity, displacement, and acceleration to situations involving objects in one dimension | ❑ define *acceleration*<br>❑ use velocity-versus-time graphs to determine acceleration, given appropriate data<br>❑ solve a range of problems for objects with constant acceleration involving<br>– displacement<br>– initial velocity<br>– final velocity<br>– acceleration<br>– time<br>❑ recognize that a projectile experiences a constant downward acceleration due to gravity if friction is ignored<br>❑ solve projectile motion problems involving<br>– displacement<br>– initial velocity<br>– final velocity<br>– acceleration due to gravity<br>– time |

## Key Elements: Forces

**Estimated Time: 14–16 hours**

By the end of this course, students will understand the nature of various forces, notably gravity and friction.

### *Vocabulary*

acceleration, average velocity, change in length, coefficient of friction, constant acceleration, displacement, final velocity, force, friction, gravitational field strength, gravity, initial velocity, instantaneous velocity, kinetic, mass, scalar, static, universal gravitational constant, vector, velocity, weight

### *Knowledge*

- mass
- force
- force due to gravity (weight)
- force due to friction (static and kinetic)
- normal force
- coefficient of friction
- inverse square law
- Newton's law of universal gravitation
- universal gravitational constant
- gravitational field strength
- Hooke's law
- spring constant
- change in length

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- apply models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
- use appropriate units and metric prefixes

## FORCES

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| D1 solve problems involving the force of gravity | ❑ recognize the relationship between<br>– mass and attractive force due to gravity (e.g., force due to gravity on the Earth's surface is proportional to Earth's mass)<br>– the force of gravity between two objects and their distance of separation (i.e., the inverse square law)<br>❑ define *gravitational field strength*<br>❑ solve a variety of problems involving the relationship between<br>– mass<br>– gravitational field strength<br>– force due to gravity (weight)<br>❑ use Newton's law of universal gravitation to solve problems involving<br>– force<br>– mass<br>– distance of separation<br>– universal gravitational constant |
| D2 analyse situations involving the force due to friction | ❑ define *static friction* and *kinetic friction*<br>❑ define *normal force*<br>❑ with teacher support, conduct experiments investigating force due to friction, involving<br>– normal force<br>– various types of material<br>– surface area<br>– speed<br>❑ define *coefficient of friction*<br>❑ recognize the relationship between force due to friction and the strengths of normal force and coefficient of friction<br>❑ solve problems with objects sliding on horizontal surfaces, involving<br>– force of friction<br>– coefficient of friction<br>– normal force |
| D3 apply Hooke's law to the deformation of materials | ❑ state Hooke's law<br>❑ define *spring constant*<br>❑ with teacher support, conduct experiments to verify Hooke's law<br>❑ use Hooke's law to solve problems that involve<br>– force<br>– spring constant<br>– change in length |

## Key Elements: Newton's Laws

**Estimated Time: 9–11 hours**

By the end of this course, students will be able to use an understanding of Newton's laws to describe the effects of forces on objects.

### *Vocabulary*

acceleration, action/reaction forces, free-body diagram, inertia, mass, net force

### *Knowledge*

- inertia
- net force
- action/reaction forces
- Newton's three laws of motion

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- produce and interpret graphs (e.g., slope and intercept)
- create free-body diagrams in one dimension
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- apply models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
- use appropriate units and metric prefixes

## NEWTON'S LAWS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| E1 solve problems that involve application of Newton's laws of motion in one dimension | ❑ state Newton's three laws of motion<br>❑ illustrate Newton's first and third laws with examples<br>❑ create free-body diagrams in one dimension for use in solving problems (e.g., elevator problems)<br>❑ use Newton's second law to solve problems that involve<br>– net force<br>– mass<br>– acceleration<br>❑ apply Newton's laws and the concepts of kinematics to solve problems |

## Key Elements: Momentum

**Estimated Time: 9–11 hours**

By the end of this course, students will have an understanding of momentum and the role it plays in various collisions and explosions.

### *Vocabulary*

collisions, explosions, impulse (change in momentum), momentum

### *Knowledge*

- momentum (initial and final)
- impulse
- isolated, one-dimensional systems
- law of conservation of momentum
- collisions and explosions

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- apply models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
- use appropriate units and metric prefixes

## MOMENTUM

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| F1 apply the concept of momentum in one dimension | ❑ define *momentum*<br>❑ solve a variety of problems involving<br>– momentum<br>– mass<br>– velocity<br>❑ define *impulse* (i.e., change in momentum)<br>❑ solve a variety of problems involving<br>– momentum (initial and final)<br>– impulse<br>– net force<br>– time<br>❑ state the law of conservation of momentum for isolated, one-dimensional systems<br>❑ solve problems, using the law of conservation of momentum (e.g., collisions and explosions) to determine<br>– momentum (initial and final)<br>– velocity (initial and final)<br>– mass |

## Key Elements: Energy

**Estimated Time: 14–16 hours**

By the end of this course, students will recognize three main forms of energy and be able to perform calculations involving the law of conservation of energy.

### *Vocabulary*

efficiency, energy, gravitational potential energy, kinetic energy, power, specific heat capacity, temperature, thermal energy, work

### *Knowledge*

- work
- gravitational potential energy
- height above a reference point
- kinetic energy
- thermal energy
- specific heat capacity
- temperature
- work as change in energy
- total energy
- the law of conservation of energy
- power
- work (input and output)
- efficiency

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- apply models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
- use appropriate units and metric prefixes

## ENERGY

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br>*Students who have fully met the prescribed learning outcome are able to:* |
| G1 perform calculations involving work, force, and displacement | ❑ define *work* in terms of force and displacement<br>❑ solve a variety of problems involving<br>– work<br>– force<br>– displacement |
| G2 solve problems involving different forms of energy | ❑ define *energy*<br>❑ define *gravitational potential energy*<br>❑ solve a variety of problems involving<br>– gravitational potential energy<br>– mass<br>– acceleration due to gravity<br>– height above a reference point<br>❑ define *kinetic energy*<br>❑ solve a variety of problems involving<br>– kinetic energy<br>– mass<br>– velocity<br>❑ define *temperature, thermal energy*, and *specific heat capacity*<br>❑ solve a variety of problems involving<br>– thermal energy<br>– mass<br>– specific heat capacity<br>– change in temperature |
| G3 analyse the relationship between work and energy, with reference to the law of conservation of energy | ❑ relate energy change to work done<br>❑ state the law of conservation of energy<br>❑ solve problems, using the law of conservation of energy to determine<br>– gravitational potential energy<br>– total energy<br>– kinetic energy<br>– thermal energy |
| G4 solve problems involving power and efficiency | ❑ define *power*<br>❑ perform calculations involving relationships among<br>– power<br>– work<br>– time<br>– define *efficiency*<br>❑ perform calculations involving relationships among<br>– work (input and output)<br>– power (input and output)<br>– efficiency |

## Key Elements: Special Relativity

**Estimated Time: 4–6 hours**

By the end of this course, students will understand the fundamental principles of special relativity.

### *Vocabulary*

inertial reference frame, length contraction, mass increase, null result, relativistic mass, relativistic multiplier, rest mass, speed of light, time dilation

### *Knowledge*

- Michelson-Morley experiment
- special theory of relativity
- relativity principle
- constancy of the speed of light
- relativistic effects of time dilation, length contraction, and mass increase
- equivalence of energy and mass
- objects not exceeding the speed of light in a vacuum
- simultaneous events

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- apply models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
- use appropriate units and metric prefixes

## SPECIAL RELATIVITY

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| H1 explain the fundamental principles of special relativity | ❑ define *inertial reference frame*<br>❑ explain why simultaneous events for one observer may not be simultaneous for another observer<br>❑ describe the Michelson-Morley experiment, and explain the significance of the "null result"<br>❑ state the two postulates of the special theory of relativity:<br>– the relativity principle<br>– the constancy of the speed of light<br>❑ describe and give examples of the relativistic effects of time dilation, length contraction, and mass increase<br>❑ calculate relativistic time dilation, length contraction, and mass increase<br>❑ explain, by using relativistic mass increase or relativistic addition of velocities, why objects cannot exceed the speed of light in a vacuum<br>❑ describe the equivalence of energy and mass, and solve problems involving<br>– energy<br>– mass<br>– speed of light |

## Key Elements: Nuclear Fission and Fusion

**Estimated Time: 4–6 hours**

By the end of this course, students will have a basic understanding of nuclear processes.

### *Vocabulary*

chain reaction, critical mass, fission, fusion, moderator

### *Knowledge*

- fusion and fission reactions
- chain reaction, critical mass, and moderator
- different types of nuclear reactors
- advantages and disadvantages of using nuclear energy

### *Skills and Attitudes*

- systematically gather and organize data
- apply models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems
- use appropriate units and metric prefixes

## Nuclear Fission and Fusion

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br>*Students who have fully met the prescribed learning outcome are able to:* |
| I1 analyse nuclear processes | ❑ compare fusion and fission reactions and give examples<br>❑ define *chain reaction, critical mass,* and *moderator*<br>❑ compare different types of nuclear reactors<br>❑ describe the advantages and disadvantages of using nuclear energy |

# Student Achievement

## *Physics 12*

# PHYSICS 12 FORMULAE

### *Vector Kinematics in Two Dimensions*

$v = v_0 + at$ $\qquad \bar{v} = \dfrac{v + v_0}{2}$

$v^2 = v_0^2 + 2ad$ $\qquad d = v_0 t + \dfrac{1}{2}at^2$

### *Vector Dynamics*

$F_{net} = ma$ $\qquad F_g = mg$

$F_{fr} = \mu F_N$

### *Work, Energy, and Power*

$W = Fd$ $\qquad E_p = mgh$

$E_k = \dfrac{1}{2}mv^2$ $\qquad P = \dfrac{W}{\Delta t}$

### *Momentum*

$p = mv$ $\qquad \Delta p = F_{net}\,\Delta t$

### *Equilibrium*

$\tau = Fd$

### *Circular Motion*

$T = \dfrac{1}{f}$ $\qquad a_c = \dfrac{v^2}{r} = \dfrac{4\partial^2 r}{T^2}$

$F_c = ma_c$

### *Gravitation*

$F_g = \mathrm{G}\dfrac{m_1 m_2}{r^2}$

### *Electrostatics*

$F = \mathrm{k}\dfrac{Q_1 Q_2}{r^2}$ $\qquad E = \dfrac{F}{Q}$ $\qquad E = \mathrm{k}\dfrac{Q}{r^2}$

$\Delta V = \dfrac{\Delta E_p}{Q}$ $\qquad E = \dfrac{\Delta V}{d}$

$E_p = \mathrm{k}\dfrac{Q_1 Q_2}{r}$ $\qquad V = \mathrm{k}\dfrac{Q}{r}$

### *Electric Circuits*

$I = \dfrac{Q}{\Delta t}$ $\qquad V = IR$

$P = IV$ $\qquad V_{terminal} = \mathcal{E} \pm Ir$

### *Electromagnetism*

$F = BIl$ $\qquad F = QvB$

$B = \mu_0 nI = \mu_0 \dfrac{N}{l} I$ $\qquad \mathcal{E} = Blv$

$\Phi = BA$ $\qquad \mathcal{E} = -N\dfrac{\Delta \Phi}{\Delta t}$

$V_{back} = \mathcal{E} - Ir$ $\qquad \dfrac{V_s}{V_p} = \dfrac{N_s}{N_p} = \dfrac{I_p}{I_s}$

## Key Elements: Experiments and Graphical Methods

**Estimated Time: integrated with other curriculum organizers**

By the end of this course, students will be able to conduct experiments and apply graphical methods to the results.

### *Vocabulary*

coefficient, intercept, inverse, inverse square, linear, proportionality constant, slope, square

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- use appropriate units and metric prefixes

## EXPERIMENTS AND GRAPHICAL METHODS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br>*Students who have fully met the prescribed learning outcome are able to:* |
| A1 conduct appropriate experiments | ❑ with teacher support, conduct appropriate experiments (e.g., projectile motion, back emf from a motor, circuits, collisions)<br>❑ systematically gather and organize data from experiments |
| A2 use graphical methods to analyse results of experiments | ❑ produce and interpret graphs (e.g., slope and intercept)<br>❑ verify relationships (e.g., linear, inverse, square, and inverse square) between variables<br>❑ use models (e.g., physics formulae, diagrams, graphs) to solve a variety of problems<br>❑ use appropriate units and metric prefixes |

## Key Elements: Vectors

**Estimated Time: 2–3 hours**

By the end of this course, students will be able to draw vector diagrams and add and subtract vectors.

### *Vocabulary*

orthogonal components, resultant vector, scalar, vector

### *Knowledge*

- scalars and vectors
- resolving a vector into two orthogonal components
- addition of two or more vectors
- subtraction of two vectors

### *Skills and Attitudes*

- write vector equations and create vector diagrams
- use vector diagrams to solve problems
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- use appropriate units and metric prefixes

## VECTORS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| B1 perform vector analysis in one or two dimensions | ❑ identify scalars and vectors<br>❑ resolve a vector into two orthogonal components using a diagram and/or trigonometry<br>❑ write equations describing the addition of two or more vectors<br>❑ write equations describing the subtraction of two vectors<br>❑ add or subtract vectors using vector diagrams and/or trigonometry<br>❑ identify the resultant vector on a vector diagram |

## Key Elements: Kinematics

**Estimated Time: 6–8 hours**

By the end of this course, students will be able to describe objects in motion in one or two dimensions, using the principles of kinematics.

### *Vocabulary*

acceleration, acceleration due to gravity, average velocity, constant acceleration, displacement, final velocity, horizontal motion, horizontal velocity, initial velocity, kinematics, maximum height, projectile motion, projectile velocity, range, relative velocity, time, velocity, vertical motion, vertical velocity

### *Knowledge*

- velocity: initial, average, final, horizontal, vertical
- navigation problems
- displacement
- acceleration due to gravity
- constant acceleration due to gravity
- shape of the path taken by a projectile fired at some angle above the horizon
- independence of horizontal and vertical motion of a projectile
- projectile motion

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae) to solve problems
- construct vector diagrams
- use appropriate units and metric prefixes

## KINEMATICS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| C1 apply vector analysis to solve practical navigation problems | ❑ describe relative velocity<br>❑ determine velocities, displacement, and time of travel for navigation problems (e.g., airplanes, boats, swimmers) |
| C2 apply the concepts of motion to various situations where acceleration is constant | ❑ solve a variety of kinematic problems involving<br>– displacement<br>– initial velocity<br>– final velocity<br>– average velocity<br>– acceleration<br>– time<br>❑ describe the shape of the path taken by a projectile fired at some angle above the horizon if friction is negligible<br>❑ with teacher support, conduct an experiment to establish the independence of a projectile's horizontal and vertical motion<br>❑ draw conclusions about a projectile's horizontal velocity and downward acceleration due to gravity if friction is discounted<br>❑ resolve a projectile's velocity into horizontal and vertical components<br>❑ solve projectile motion problems involving<br>– range<br>– maximum height<br>– time of flight<br>– displacement<br>– velocity<br>– acceleration due to gravity |

## Key Elements: Dynamics

**Estimated Time: 8–10 hours**

By the end of this course, students will be able to apply Newton's laws of motion to one- and two-dimensional situations.

### *Vocabulary*

coefficient of friction, direction, dynamics, force as a vector quantity, force of friction, free-body diagrams, gravitational field strength, gravity, magnitude, net force, Newton's three laws of motion, normal force, orthogonal components, unbalanced forces

### *Knowledge*

- Newton's three laws of motion
- net force
- gravitational field strength
- the force of gravity (weight)
- force of friction
- coefficient of friction
- normal force
- force as a vector quantity
- unbalanced forces

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- construct vector and free-body diagrams
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- use appropriate units and metric prefixes

## DYNAMICS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| D1 apply Newton's laws of motion to solve problems involving acceleration, gravitational field strength, and friction | ❑ state Newton's three laws of motion<br>❑ illustrate Newton's first and third laws with examples<br>❑ solve problems involving Newton's second law, to determine<br>– net force<br>– mass<br>– acceleration<br>❑ define *gravitational field strength*<br>❑ solve problems involving<br>– the force of gravity (weight)<br>– gravitational field strength<br>– mass<br>❑ solve problems involving<br>– force of friction<br>– coefficient of friction<br>– normal force |
| D2 apply the concepts of dynamics to analyse one-dimensional or two-dimensional situations | ❑ describe force as a vector quantity<br>❑ resolve a force into two orthogonal components<br>❑ determine the magnitude and direction of a force, given its two orthogonal components<br>❑ determine the net force from two or more forces<br>❑ construct free-body diagrams<br>❑ solve a variety of problems related to unbalanced forces (e.g., sliding objects, Atwood's machine, inclined planes) |

## Key Elements: Work, Energy, and Power

**Estimated Time: 5–7 hours**

By the end of this course, students will understand the relationship between work, energy, and power and be able to apply the law of conservation of energy.

### *Vocabulary*

efficiency, energy, gravitational potential energy, kinetic energy, power, work

### *Knowledge*

- work
- energy
- kinetic energy
- gravitational potential energy
- work-energy theorem
- law of conservation of energy
- power
- efficiency

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- use appropriate units and metric prefixes

## WORK, ENERGY, AND POWER

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| E1 analyse the relationships among work, energy, and power | ❑ define *work*<br>❑ solve a range of problems involving<br>– work<br>– force<br>– displacement<br>❑ determine graphically the amount of work done on objects by constant or linearly varying forces<br>❑ define *energy*<br>❑ state the work-energy theorem, $W_{net} = \Delta E_k$<br>❑ differentiate between *kinetic energy* and *gravitational potential energy*, and give examples of each<br>❑ solve a range of problems involving<br>– kinetic energy<br>– mass<br>– gravitational potential energy<br>– height<br>– velocity<br>❑ state the law of conservation of energy, and give examples of its application in a variety of situations (e.g., falling objects, sliding objects, roller coasters)<br>❑ define *power*<br>❑ solve a range problems involving<br>– power<br>– work<br>– time<br>– efficiency |

## Key Elements: Momentum

**Estimated Time: 5–7 hours**

By the end of this course, students will have an understanding of momentum and impulse and the roles they play in one- or two-dimensional collisions and explosions.

### *Vocabulary*

change in momentum, elastic collision, impulse, inelastic collision, momentum, oblique collision

### *Knowledge*

- momentum and impulse (change in momentum)
- momenta of common objects
- law of conservation of momentum
- oblique collisions
- elastic and inelastic collisions
- objects exploding into no more than three fragments

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- construct vector diagrams
- use appropriate units and metric prefixes

## MOMENTUM

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| F1 use knowledge of momentum and impulse to analyse situations in one dimension | ❑ define *momentum* and *impulse*<br>❑ recognize that momentum and impulse are vector quantities<br>❑ identify and compare momenta of common objects<br>❑ solve a variety of problems involving<br>– net force<br>– time<br>– impulse<br>– velocity<br>– mass<br>– momentum<br>❑ state the law of conservation of momentum<br>❑ determine whether a collision is elastic or inelastic<br>❑ solve problems related to collisions or explosions, to determine<br>– mass<br>– initial velocity<br>– final velocity<br>– momentum<br>– impulse |
| F2 use knowledge of momentum and impulse to analyse situations in two dimensions | ❑ analyse conservation of momentum in two dimensions<br>❑ give examples of situations involving momentum and impulse<br>❑ for situations involving two objects in an oblique collision or an object exploding into no more than three fragments, solve problems to determine<br>– mass<br>– momentum<br>– velocity<br>– impulse |

## Key Elements: Equilibrium

**Estimated Time: 11–13 hours**

By the end of this course, students will understand the nature of static equilibrium.

### *Vocabulary*

centre of gravity, lever arm, pivot point, rotational equilibrium, static equilibrium, torque, translational equilibrium

### *Knowledge*

- translational, rotational, and static equilibrium
- pivot point
- lever arm
- torque
- centre of gravity and its location for objects of uniform shape and density

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- construct vector and free-body diagrams
- use appropriate units and metric prefixes

## Equilibrium

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| G1 use knowledge of force, torque, and equilibrium to analyse various situations | ❑ define *translational equilibrium*<br>❑ identify situations involving translational, rotational, and static equilibrium<br>❑ use free-body diagrams and vector analyses to determine the sum of the forces acting at a single point on an object<br>❑ solve problems for objects in translational equilibrium<br>❑ define *torque*, and identify situations involving the application of torque<br>❑ use free-body diagrams and vector analyses to solve problems involving<br>– torque<br>– force<br>– lever arm<br>❑ define *centre of gravity*, and determine its location for objects of uniform shape and density<br>❑ define *rotational equilibrium*<br>❑ determine the sum of the forces and of the torques on a given object<br>❑ define *static equilibrium*<br>❑ recognize that, in static equilibrium, any location can be chosen as the pivot point<br>❑ solve problems for objects in static equilibrium (e.g., diving boards, shelves, ladders, painters on scaffolds) |

## Key Elements: Circular Motion

**Estimated Time: 7–9 hours**

By the end of this course, students will understand the nature of circular motion and the net force associated with it.

### *Vocabulary*

centripetal acceleration, centripetal force, frequency, period, radius of revolution, tangential velocity, uniform circular motion

### *Knowledge*

- uniform circular motion
- radius of revolution
- period and frequency of revolution
- centripetal acceleration
- centripetal force (net force)
- forces acting on objects in circular motion
- tangential velocity

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- construct free-body diagrams
- use appropriate units and metric prefixes

## CIRCULAR MOTION

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br>*Students who have fully met the prescribed learning outcome are able to:* |
| H1 use knowledge of uniform circular motion to analyse various situations | ❑ define *uniform circular motion*<br>❑ describe the velocity of an object moving in uniform circular motion at any point in that motion<br>❑ explain how the acceleration of an object may result in a change in direction with no change in speed<br>❑ define *centripetal acceleration* and *centripetal force*<br>❑ analyse the forces acting on objects in circular motion, using free-body diagrams<br>❑ solve problems involving<br>– centripetal acceleration<br>– centripetal force<br>– speed<br>– radius of revolution<br>– period and frequency of revolution<br>– mass |

## Key Elements: Gravitation

**Estimated Time: 7–9 hours**

By the end of this course, students will understand the implications of a non-constant gravitational field for work and energy.

### *Vocabulary*

distance of separation, gravitational force, gravitational field strength, gravitational potential energy, inverse square relationship

### *Knowledge*

- Newton's law of universal gravitation
- distance of separation
- gravitational field strength
- work required to move an object in a gravitational field
- gravitational potential energy relative to zero at infinity
- satellites in circular orbits
- total energy of a satellite

### *Skills and Attitudes*

- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae) to solve problems
- construct free-body diagrams
- use appropriate units and metric prefixes

## GRAVITATION

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| I1 analyse the gravitational attraction between masses | ❑ state Newton's law of universal gravitation<br>❑ apply Newton's law of universal gravitation to solve problems involving<br>– force<br>– mass<br>– distance of separation<br>❑ describe the gravitational field strength of a body in terms of an inverse square relationship<br>❑ show the area that indicates the work required to move an object in a gravitational field on a graph of gravitational force versus distance of separation<br>❑ define *gravitational potential energy*<br>❑ solve problems involving<br>– gravitational potential energy relative to zero at infinity<br>– mass<br>– distance of separation<br>❑ calculate the work required to change the separation distance between two objects<br>❑ solve problems for satellites in circular orbits, in terms of gravitational and centripetal forces (e.g., determine the period of a planet around the Sun)<br>❑ calculate the total energy of a satellite |

## Key Elements: Electrostatics

**Estimated Time: 12–13 hours**

By the end of this course, students will have a basic understanding of electrostatic principles and be able to apply them to solve problems.

### *Vocabulary*

cathode ray tube, electric charge, electric field, electric field lines, electric force, electric potential, electric potential difference, electric potential energy, electrostatics, point charge, polarity, voltage

### *Knowledge*

- Coulomb's law
- electric fields
- electric field lines
- electric potential energy
- electric potential
- electric potential difference (voltage)
- cathode ray tube

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- construct electric field diagrams
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- construct vector and free-body diagrams
- use appropriate units and metric prefixes

## ELECTROSTATICS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| J1 apply Coulomb's law to analyse electric forces | ❑ state Coulomb's law<br>❑ use Coulomb's law to solve problems that deal with two point charges and that involve<br>– electric force<br>– charge<br>– distance of separation<br>❑ determine the electric force on a point charge due to two other point charges |
| J2 analyse electric fields and their effects on charged objects | ❑ define *electric field*<br>❑ describe and illustrate the electric field lines for simple charge distributions, including<br>– one point charge<br>– two point charges<br>– parallel plates<br>❑ solve problems that deal with positions near one or two point charges and that involve<br>– electric field<br>– charge<br>– distance<br>❑ recognize the relationship between electric force, electric field, and charge<br>❑ solve problems that deal with a charge in an electric field and that involve the relationship between the<br>– force<br>– charge<br>– electric field |
| J3 calculate electric potential energy and change in electric potential energy<br><br>*Organizer 'Electrostatics' continued on page 69* | ❑ define *electric potential energy* and *change in electric potential energy*<br>❑ solve problems that deal with two point charges at rest and that involve<br>– electric potential energy<br>– charge<br>– distance of separation<br>❑ solve problems that deal with two point charges where one is moved and that involve<br>– change in electric potential energy<br>– distance of separation (initial and final)<br>– charge |

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *Organizer 'Electrostatics' continued from page 68* | |
| J4 apply the concept of electric potential to analyse situations involving point charges | ❑ define *electric potential* and *electric potential difference* (voltage)<br>❑ solve problems that deal with a position near one or two point charges and that involve<br>– electric potential relative to zero at infinity<br>– charge<br>– distance<br>❑ solve problems that deal with two positions near one or two point charges and that involve<br>– electric potential difference<br>– charge<br>– distance |
| J5 apply the principles of electrostatics to a variety of situations | ❑ recognize that electric potential energy is the product of charge and electric potential<br>❑ use the law of conservation of energy to solve problems that deal with a charge in an electric field and that involve<br>– speed<br>– mass<br>– charge<br>– distance<br>– work<br>– electric field<br>– electric potential difference<br>❑ solve problems that deal with a charge in a constant electric field (e.g., between parallel plates) and that involve<br>– electric potential difference<br>– electric potential energy<br>– electric field<br>– distance<br>❑ qualitatively explain the operation of a cathode ray tube (CRT) |

## Key Elements: Electric Circuits

**Estimated Time: 12–14 hours**

By the end of this course, students will be able to apply Kirchhoff's laws to simple DC circuits.

### *Vocabulary*

ammeter, conventional electric current, current, electric power, electromotive force (emf), internal resistance, resistance, terminal voltage, voltmeter

### *Knowledge*

- current
- voltage (electric potential difference)
- Ohm's law
- series and parallel circuits
- schematic diagrams
- placement of ammeters and voltmeters
- equivalent (total) resistance
- Kirchhoff's laws
- electromotive force
- terminal voltage
- efficiency of electric devices

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae) to solve problems
- draw and interpret circuit diagrams
- construct circuits from schematic diagrams
- use appropriate units and metric prefixes

## ELECTRIC CIRCUITS

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| K1 apply Ohm's law and Kirchhoff's laws to direct current circuits | ❑ define *conventional electric current*, and relate it to the direction of electron flow in a conductor<br>❑ solve problems involving<br>– current<br>– time<br>– charge<br>❑ define *resistance* in terms of Ohm's law<br>❑ solve problems involving<br>– electric potential difference<br>– current<br>– resistance<br>❑ calculate the total (equivalent) resistance for resistors connected in parallel, series, or a combination of both<br>❑ state Kirchhoff's laws, and apply them to circuits containing one source of electric potential difference<br>❑ draw and interpret circuit diagrams<br>❑ construct circuits from schematic diagrams<br>❑ demonstrate the correct placement and use of an ammeter and voltmeter<br>❑ define *electromotive force (emf)*, *terminal voltage*, and *internal resistance*<br>❑ solve problems using<br>– terminal voltage<br>– electromotive force (emf)<br>– internal resistance<br>– current<br>– electric potential difference |
| K2 relate efficiency to electric power, electric potential difference, current, and resistance | ❑ define *electric power*<br>❑ solve a range of problems involving<br>– electric power<br>– electric potential difference<br>– current<br>– resistance<br>❑ define *efficiency*<br>❑ solve a range of problems involving the efficiency of electrical devices<br>❑ explain why electric energy is transmitted through transmission lines at high voltage and low current |

## Key Elements: Electromagnetism

**Estimated Time: 15–17 hours**

By the end of this course, students will be able to apply an understanding of the relationship between electricity and magnetism.

### *Vocabulary*

AC current, back emf, DC current, electromagnetic induction, electromagnetism, magnetic field line, magnetic force, magnetic flux, magnetic poles, solenoid, transformer, turns, windings

### *Knowledge*

- magnetic poles
- magnetic field line
- magnetic force
- interaction of magnetic fields and moving charges (currents)
- solenoids
- electromagnetic induction
- magnetic flux
- change in magnetic flux
- Lenz's law
- Faraday's law
- generators
- back emf (motors)
- ideal transformers

### *Skills and Attitudes*

- conduct appropriate experiments
- systematically gather and organize data from experiments
- use graphical methods to analyse results of experiments
- produce and interpret graphs (e.g., slope and intercept)
- verify relationships (e.g., linear, inverse, square, and inverse square) between variables
- use models (e.g., physics formulae, diagrams, graphs) to solve problems
- construct and interpret magnetic field diagrams
- use right-hand rules to determine field and force directions
- use appropriate units and metric prefixes

## ELECTROMAGNETISM

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
|---|---|
| *It is expected that students will:* | *The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.*<br><br>*Students who have fully met the prescribed learning outcome are able to:* |
| L1 analyse electromagnetism, with reference to magnetic fields and their effects on moving charges<br><br>*Organizer 'Electromagnetism' continued on page 74* | ❑ state the rules explaining how magnetic poles interact with each other<br>❑ describe and illustrate the direction of the magnetic field lines for a permanent magnet<br>❑ use the right-hand rule to determine the magnetic field direction for a current-carrying wire or a solenoid<br>❑ determine the direction of the force exerted on a current-carrying conductor or a moving charge that is within a magnetic field<br>❑ solve problems that deal with a current-carrying conductor placed in a magnetic field and that involve<br>– magnetic force<br>– current<br>– length of conductor in the field<br>– magnetic field<br>❑ describe the path of charged particles moving perpendicular to magnetic fields (e.g., circles or arcs of circles)<br>❑ solve problems that deal with a charge moving through a magnetic field and that involve<br>– magnetic force<br>– charge<br>– speed<br>– magnetic field<br>– centripetal force<br>– mass<br>– radius<br>❑ solve problems that deal with a solenoid and that involve<br>– current<br>– magnetic field (in the centre of the solenoid)<br>– number of turns per metre of solenoid<br>❑ apply the principles of electromagnetism to qualitatively explain the operation of a cathode-ray tube |

| Prescribed Learning Outcomes | Suggested Achievement Indicators |
| --- | --- |
| *Organizer 'Electromagnetism' continued from page 73* | |
| L2 analyse the process of electromagnetic induction | ❑ with respect to a conductor moving perpendicularly through a uniform magnetic field, solve problems involving<br>❑ electromotive force (emf) induced between the ends of the conductor<br>– speed of the conductor<br>– magnetic field<br>– length of the conductor<br>– define *magnetic flux*<br>❑ calculate the magnetic flux through a loop or coil placed parallel or perpendicular to a magnetic field<br>❑ identify, from appropriate diagrams, situations that would produce an induced emf in a coil<br>❑ use Faraday's law to solve problems involving<br>– time<br>– change in flux<br>– induced emf<br>– number of turns<br>❑ use Lenz's law to determine the direction of the induced current in a loop or coil placed in a perpendicular magnetic field<br>❑ qualitatively describe how a generator uses induction to produce an electric current<br>❑ define *back emf*<br>❑ with respect to DC motors, solve problems involving<br>– current<br>– back emf<br>– armature resistance<br>– voltage to motor<br>❑ give examples of current fluctuations due to back emf in motors (e.g., overheating)<br>❑ solve problems that deal with an ideal transformer and that involve<br>– primary voltage<br>– secondary voltage<br>– number of primary windings<br>– number of secondary windings<br>– primary current<br>– secondary current<br>– identify a transformer as step-up or step-down<br>❑ give examples of the use of transformers in the home, workplace, and community |

# Learning Resources

*Physics 11 and 12*

This section contains general information on learning resources, and provides a link to the titles, descriptions, and ordering information for the recommended learning resources in the Physics 11 and 12 Grade Collections.

***What Are Recommended Learning Resources?***
Recommended learning resources are resources that have undergone a provincial evaluation process using teacher evaluators and have Minister's Order granting them provincial recommended status. These resources may include print, video, software and CD-ROMs, games and manipulatives, and other multimedia formats. They are generally materials suitable for student use, but may also include information aimed primarily at teachers.

Information about the recommended resources is organized in the format of a Grade Collection. A Grade Collection can be regarded as a "starter set" of basic resources to deliver the curriculum. In many cases, the Grade Collection provides a choice of more than one resource to support curriculum organizers, enabling teachers to select resources that best suit different teaching and learning styles. Teachers may also wish to supplement Grade Collection resources with locally approved materials.

***How Can Teachers Choose Learning Resources to Meet Their Classroom Needs?***
Teachers must use either:

- provincially recommended resources OR
- resources that have been evaluated through a local, board-approved process

Prior to selecting and purchasing new learning resources, an inventory of resources that are already available should be established through consultation with the school and district resource centres. The ministry also works with school districts to negotiate cost-effective access to various learning resources.

***What Are the Criteria Used to Evaluate Learning Resources?***
The Ministry of Education facilitates the evaluation of learning resources that support BC curricula, and that will be used by teachers and/or students for instructional and assessment purposes. Evaluation criteria focus on content, instructional design, technical considerations, and social considerations.

Additional information concerning the review and selection of learning resources is available from the ministry publication, *Evaluating, Selecting and Managing Learning Resources: A Guide* (Revised 2002)
www.bced.gov.bc.ca/irp/resdocs/esm_guide.pdf

***What Funding is Available for Purchasing Learning Resources?***
As part of the selection process, teachers should be aware of school and district funding policies and procedures to determine how much money is available for their needs. Funding for various purposes, including the purchase of learning resources, is provided to school districts. Learning resource selection should be viewed as an ongoing process that requires a determination of needs, as well as long-term planning to co-ordinate individual goals and local priorities.

***What Kinds of Resources Are Found in a Grade Collection?***
The Grade Collection charts list the recommended learning resources by media format, showing links to the curriculum organizers and suborganizers. Each chart is followed by an annotated bibliography. Teachers should check with suppliers for complete and up-to-date ordering information. Most suppliers maintain web sites that are easy to access.

## PHYSICS 11 AND 12 GRADE COLLECTIONS

The Grade Collections for Physics 11 and 12 list the recommended learning resources for these courses. Resources previously recommended for the 1996 version of the curriculum, where still valid, continue to support this updated IRP. The ministry updates the Grade Collections on a regular basis as new resources are developed and evaluated.

Please check the following ministry web site for the most current list of recommended learning resources in the Physics 11 and 12 Grade Collections: www.bced.gov.bc.ca/irp_resources/lr/resource/gradcoll.htm