Advanced Physics 11 and Advanced Physics 12

Guide

NOVA SCOTIA
NOUVELLE-ÉCOSSE

2009

Website References

Website references contained within this document are provided solely as a convenience and do not constitute an endorsement by the Department of Education of the content, policies, or products of the referenced website. The department does not control the referenced websites and subsequent links, and is not responsible for the accuracy, legality, or content of those websites. Referenced website content may change without notice.

Regional Education Centres and educators are required under the Department's Public School Programs Network Access and Use Policy to preview and evaluate sites before recommending them for student use. If an outdated or inappropriate site is found, please report it to <curriculum@novascotia.ca>.

Advanced Physics 11 and Advanced Physics 12

Prepared by the Department of Education and Early Childhood Development

This is the most recent version of the current curriculum materials as used by teachers in Nova Scotia.

Advanced Physics 11 and Advanced Physics 12

Acknowledgments

The Nova Scotia Department of Education expresses its indebtedness to physics teachers, university professors, community college instructors, and our educational colleagues for their professional expertise and insights in developing this regional Advanced Physics 11 and Advanced Physics 12 curriculum guide. In addition, pilot teachers and others who contributed comments and suggestions are to be commended for their commitment to developing exemplary science programs.

Foreword

The pan-Canadian *Common Framework of Science Learning Outcomes K to 12* (1997) provides a framework for standardizing science education across the country. Science curriculum for the Atlantic provinces is described in *Foundation for the Atlantic Canada Science Curriculum* (1998).

This guide is intended to provide teachers with an overview of the outcomes framework for the advanced courses. It also includes some suggestions to assist teachers in designing learning experiences and assessment tasks.

Contents

Introduction

The aim of science education in the Atlantic provinces is to develop scientific literacy.

Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge that students need in order to develop inquiry, problem-solving, and decision-making abilities; to become lifelong learners; and to maintain a sense of wonder about the world around them. To develop scientific literacy, students require diverse learning experiences that provide opportunities to explore, analyse, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, their careers, and their futures.

Advanced science courses offer expanded and extended learning outcomes in both the theoretical and applied aspects of science. The Department of Education has worked with physics teachers, university professors, and other interested parties to establish a set of principles to guide the development of advanced physics courses.

Advanced physics courses build on the curriculum prescribed for academic physics courses and may be offered in discrete classes or in classes together with the academic level courses. The advanced courses are distinguished by three parts of increased depth in certain parts of the curriculum. These are numerical problem solving, a literature search and report, and an independent study/experiment.

Numerical problem solving is enhanced by the inclusion of more situations presented in variable terms only (no numbers), as well as a selection of more challenging application problems.

Advanced physics courses require students to do an independent study/experiment and to present the results visually, orally, and in written report form. *A Closer Look: Doing Project-based Science* is a useful resource for this component of the courses. It is important that students be encouraged to investigate the science involved in a topic of personal interest, such as vehicle safety, music and musical instruments, energy for the future, or sports. Project-based learning provides students with an opportunity to demonstrate their initiative and perseverance. These qualities are essential for success in continued study and eventual employment.

This guide is organized as a supplement to *Atlantic Canada Science Curriculum: Physics 11 and Physics 12* (2002).

Advanced Physics 11 and Advanced Physics 12, like other Public School Programs advanced courses, will be available for in-class and online delivery to give more students the opportunity to take advanced courses.

Program Design and Components

Learning and Teaching Science

What students learn is fundamentally connected to how they learn it. The aim of scientific literacy for all has created a need for new forms of classroom organization, communication, and instructional strategies. The teacher is a facilitator of learning whose major tasks include

- creating a classroom environment to support the learning and teaching of science
- designing effective learning experiences that help students achieve designated outcomes
- stimulating and managing classroom discourse in support of student learning
- learning about and then using students' motivations, interests, abilities, and learning styles to improve learning and teaching
- assessing student learning, the scientific tasks and activities involved, and the learning environment to make ongoing instructional decisions
- selecting teaching strategies from a wide repertoire

Effective science learning and teaching take place in a variety of situations. Instructional settings and strategies should create an environment that reflects a constructive, active view of the learning process. Learning occurs through actively constructing one's own meaning and assimilating new information to develop a new understanding.

The development of scientific literacy in students is a function of the kinds of tasks in which they engage, the discourse in which they participate, and the settings in which these activities occur. Students' disposition towards science is also shaped by these factors. Consequently, the aim of developing scientific literacy requires careful attention to all of these facets of curriculum.

Learning experiences in science education should vary and should include opportunities for group and individual work, discussion among students as well as between teacher and students, and hands-on/minds-on activities that allow students to construct and evaluate explanations for the phenomena under investigation. Such investigations and the evaluation of the evidence accumulated provide opportunities for students to develop their understanding of the nature of science and the nature and status of scientific knowledge.

Students in Advanced Physics 11 and Advanced Physics 12 are expected to meet all of the outcomes that are in Physics 11 and Physics 12. The depth of treatment is the major distinction. Advanced physics requires an in-depth treatment of physics concepts, a major literature search and report, and a hands-on investigation of a major physical concept.

Generally, advanced physics should attract students who have a high level of science interest and are strong independent learners. Students will be identified by science teachers or in consultation with administration and counsellors. These students may wish to pursue further study at a post-secondary level and/or careers in science, engineering, or technology.

Advanced Physics 11 is built on four content areas: Kinematics, Dynamics, Momentum and Energy, and Waves. The following table lists the time allocations.

Comparison: Physics 11 and Advanced Physics 11

Topic	Physics 11 (hours)	Advanced Physics 11 (hours)	Enhancement
Presenting Vectors	2	2	
Vector Analysis	3	3	
Algebraic Problem Solving	5	5	Math connection: Show that slope and area relate to calculus.
Dynamics Introduction	5	3	Saving five hours here can free time to begin an independent study/experiment.
Newton's Laws	8	5	
Introduction to Momentum	2	2	
Conservation of Momentum	5	5	
Work, Power, and Efficiency	5	5	
Transformation, Total Energy, and Conservation	15	10	Note five-hour difference. Use time to work on Independent Study/Experiment.
Technological Implications	5	5	
Fundamental Properties of Waves	12	12	
Sound Waves and Electromagnetic Radiation	15	20	Note five hours added to do more ray optics.
Total minimum time allocation of the 110 hours	87	77	

Advanced Physics 12 is built on Force, Motion, Work, and Energy; Fields; Waves and Modern Physics; and Radioactivity.

Comparison: Physics 12 and Advanced Physics 12

Topic	Physics 12 (hours)	Advanced Physics 12 (hours)	Enhancement
Dynamics Extension	10	10	Begin an independent study/experiment.
Collisions in Two Dimensions	8	6	More emphasis is placed on derivations and higher-level problems.
Projectiles	8	6	
Circular Motion	8	6	
Simple Harmonic Motion	4	4	
Universal Gravitation	5	5	
Magnetic, Gravitational, and Electric Fields	4	3	Circuits will include Ohm law, series, parallel, and combination circuits.
Coloumb Law	4	3	
Electric Circuits	optional	5	
Electromagnetism and Induction	5	4	
Generators and Motors	4	3	
Quantum Physics	3	3	
Compton and de Broglie	2	2	
Particles and Waves	2	2	
Bohr and Quantum Atoms	3	3	
Natural and Artificial Sources of Radiation	3	3	
Radioactive Decay	3	3	
Fission and Fusion	4	4	
Total minimum time allocation of the 110 hours	**80**	75	

Writing in Science

Learning experiences should provide opportunities for students to use writing and other forms of representation as ways of learning. Students, at all grade levels, should be encouraged to use writing to speculate, theorize, summarize, discover connections, describe processes, express understandings, raise questions, and make sense of new information using their own language as a step to the language of science. Science logs are useful for such expressive and reflective writing. Purposeful note making is an intrinsic part of learning in science, helping students to better record, organize, and understand information from a variety of sources. The process of creating word webs, maps, charts, tables, graphs, drawings, and diagrams to represent data and results helps students learn and also provides them with useful study tools.

Learning experiences in science should also provide abundant opportunities for students to communicate their findings and understandings to others, both formally and informally, using a variety of forms for a range of purposes and audiences. Such experiences should encourage students to use effective ways of recording and conveying information and ideas and to use the vocabulary of science in expressing their understandings. Through opportunities to talk and write about the concepts they need to learn, students come to better understand both the concepts and related vocabulary.

Learners will need explicit instruction in, and demonstration of, the strategies they need to develop and apply in reading, viewing, interpreting, and using a range of science texts for various purposes. It will be equally important for students to have demonstrations of the strategies they need to develop and apply in selecting, constructing, and using various forms for communicating in science.

The Three Processes of Scientific Literacy

An individual can be considered scientifically literate when he/she is familiar with, and able to engage in, three processes: inquiry, problem solving, and decision making.

Inquiry

Scientific inquiry involves posing questions and developing explanations for phenomena. While there is general agreement that there is no such thing as the scientific method, students require certain skills to participate in the activities of science. Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, collecting data, analysing data, and interpreting data are fundamental to engaging in science. These activities provide students with opportunities to understand and practise the process of theory development in science and the nature of science.

Problem Solving

The process of problem solving involves seeking solutions to human problems. It consists of proposing, creating, and testing prototypes, products, and techniques to determine the best solution to a given problem.

Decision Making

The process of decision making involves determining what we, as citizens, should do in a particular context or in response to a given situation. Decision-making situations are important in their own right, and they also provide a relevant context for engaging in scientific inquiry and/or problem solving.

Meeting the Needs of All Learners

Foundation for the Atlantic Canada Science Curriculum stresses the need to design and implement a science curriculum that provides equitable opportunities for all students according to their abilities, needs, and interests. Teachers must be aware of, and make adaptations to accommodate, the diverse range of learners in their classes. To adapt instructional strategies, assessment practices, and learning resources to the needs of all learners, teachers must create opportunities that will permit them to address their students' various learning styles.

As well, teachers must not only remain aware of and avoid gender and cultural biases in their teaching, they must also actively address cultural and gender stereotyping (e.g., about who is interested in and who can succeed in science and mathematics). Research supports the position that when science curriculum is made personally meaningful and socially and culturally relevant, it is more engaging for groups traditionally under-represented in science and, indeed, for all students.

While this curriculum guide presents specific outcomes for each unit, it must be acknowledged that students will progress at different rates.

Teachers should provide materials and strategies that accommodate student diversity and should validate students when they achieve the outcomes to the best of their abilities.

It is important that teachers articulate high expectations for all students and ensure that all students have equitable opportunities to experience success as they work toward achieving designated outcomes. Teachers should adapt classroom organization, teaching strategies, assessment practices, time, and learning resources to address students' needs and build on their strengths. The variety of learning experiences described in this guide provides access for a wide range of learners. Similarly, the suggestions for a variety of assessment practices provide multiple ways for learners to demonstrate their achievements.

Assessment and Evaluation

The terms **assessment** and **evaluation** are often used interchangeably, but they refer to quite different processes. Science curriculum documents developed in the Atlantic region use these terms for the processes described below.

Assessment is the systematic process of gathering information on student learning.

Evaluation is the process of analysing, reflecting upon, and summarizing assessment information and making judgments or decisions based upon the information gathered.

The assessment process provides the data, and the evaluation process brings meaning to the data. Together, these processes improve teaching and learning. If we are to encourage enjoyment in learning for students now and throughout their lives, we must develop strategies to involve students in assessment and evaluation at all levels. When students are aware of the outcomes for which they are responsible and of the criteria by which their work will be assessed or evaluated, they can make informed decisions about the most effective ways to demonstrate their learning.

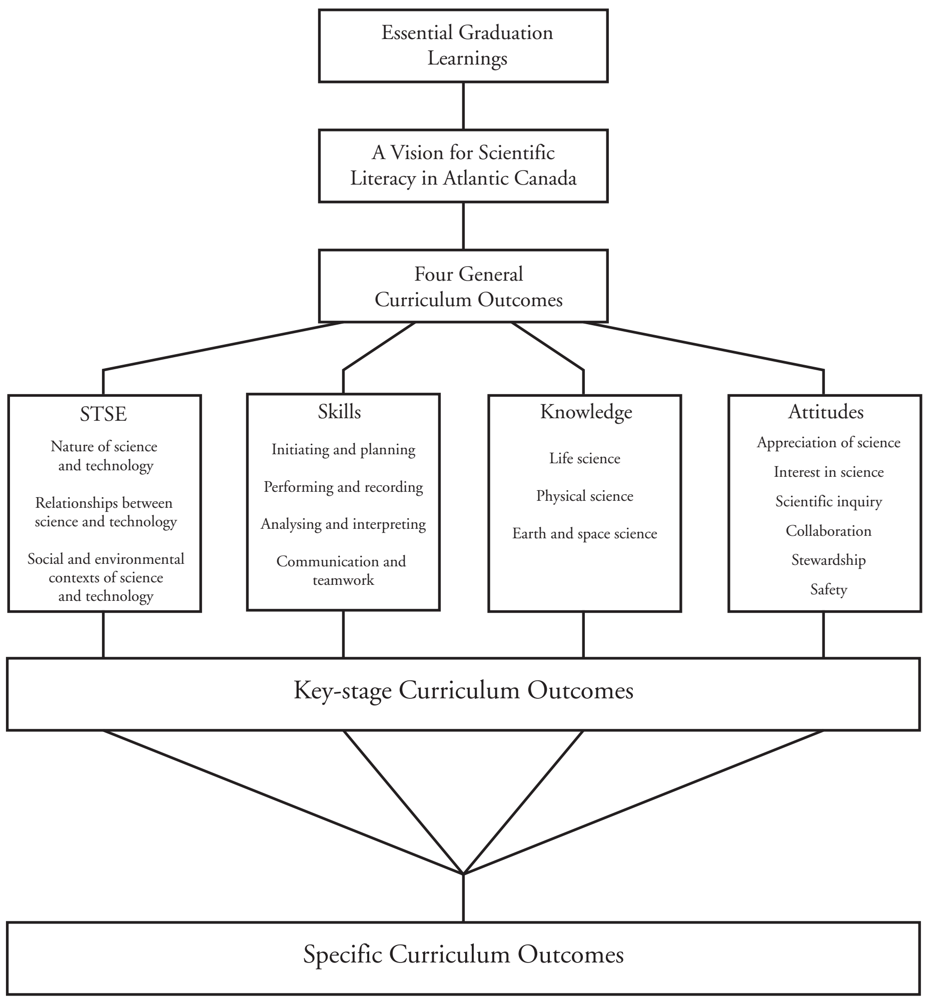
The Atlantic Canada science curriculum reflects the three major processes of science learning: inquiry, problem solving, and decision making. When assessing student progress, it is helpful to know some activities/skills/actions that are associated with each process of science learning. Student learning may be described in terms of ability to perform these tasks.

Curriculum Outcomes Framework

Overview

The science curriculum is based on an outcomes framework that includes statements of essential graduation learnings, general curriculum outcomes, key-stage curriculum outcomes, and specific curriculum outcomes. The general, key-stage, and specific curriculum outcomes reflect the pan-Canadian C*ommon Framework of Science Learning Outcomes K to 12*. The diagram below provides the blueprint of the outcomes framework.

Outcomes Framework



Essential Graduation Learnings

Essential graduation learnings are statements describing the knowledge, skills, and attitudes expected of all students who graduate from high school. Achievement of the essential graduation learnings will prepare students to continue to learn throughout their lives. These learnings describe expectations not in terms of individual school subjects but in terms of knowledge, skills, and attitudes developed throughout the curriculum. They confirm that students need to make connections and develop abilities across subject boundaries and be ready to meet the shifting and ongoing opportunities, responsibilities, and demands of life after graduation. Provinces may add additional essential graduation learnings as appropriate. The essential graduation learnings are described below.

Aesthetic Expression

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

Citizenship

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

Communication

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

Personal Development

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

Problem Solving

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

Technological Competence

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

General Curriculum Outcomes

The general curriculum outcomes form the basis of the outcomes framework. They also identify the key components of scientific literacy. Four general curriculum outcomes have been identified to delineate the four critical aspects of students' scientific literacy. They reflect the wholeness and interconnectedness of learning and should be considered interrelated and mutually supportive.

Science, Technology, Society, and the Environment (STSE)

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

Skills

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

Knowledge

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

Attitudes

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

Key-Stage Curriculum Outcomes

Key-stage curriculum outcomes are statements that identify what students are expected to know, be able to do, and value by the end of grades 3, 6, 9, and 12 as a result of their cumulative learning experiences in science. The key-stage curriculum outcomes are from the *Common Framework of Science Learning Outcomes K to 12.*

Specific Curriculum Outcomes

Specific curriculum outcome statements describe what students are expected to know and be able to do at each grade level. They are intended to help teachers design learning experiences and assessment tasks. Specific curriculum outcomes represent a framework for assisting students to achieve the key-stage curriculum outcomes, the general curriculum outcomes, and ultimately, the essential graduation learnings.

This curriculum guide outlines specific curriculum outcomes for advanced physics and provides suggestions for learning, teaching, assessment, and resources to support students' achievement of these outcomes. Teachers should consult *Foundation for the Atlantic Canada Science Curriculum* for descriptions of the essential graduation learnings, vision for scientific literacy, general curriculum outcomes, and key-stage curriculum outcomes.

Specific curriculum outcomes are organized in four units. Each unit is organized by topic. Advanced Physics 11 and Advanced Physics 12 units and topics use Physics 11 and Physics 12 outcomes, but the following are done in more depth.

Advanced Physics 11

The following outcomes are from the Physics 11 guide. The topic from the unit and two-page spread are identified with the outcome.

Kinematics

Vector Analysis

Students will be expected to

- use vectors to represent position, displacement, velocity, and acceleration (325-5)

Presenting Vectors

Students will be expected to

- identify and investigate questions that arise from practical problems/ issues involving motion (212-1)

Algebraic Problem Solving

Students will be expected to

- analyse word problems, solve algebraically for unknowns, and interpret patterns in data (325-2)

Momentum and Energy

Transformation, Total Energy, and Conservation

Students will be expected to

- design an experiment, select and use appropriate tools, carry out procedures, compile and organize data, and interpret patterns in the data to answer a question posed regarding the conservation of energy (212-3, 212-8, 213-2, 214-3, 214-5, 214-11, 326-4)
- analyse quantitatively the relationships among mass, speed, kinetic energy, and heat using the law of conservation of energy (326-1)

Conservation of Momentum

Students will be expected to

- apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions (326-3)

Work, Power, and Efficiency

Students will be expected to

- design and carry out an experiment to determine the efficiency of various machines (212-3, 213-2, 213-3, 214-7)

Waves: Sound Waves and Electromagnetic Radiation

Students will be expected to

- describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves (327-1)

Advanced Physics 12

The following outcomes are from the Physics 12 guide. The topic from the unit and two-page spread are identified with the outcome.

Force, Motion, Work, and Energy

Dynamics Extension

Students will be expected to

- use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques (ACP-1)

Projectiles

Students will be expected to

- analyse quantitatively the horizontal and vertical motion of a projectile (325-6)

Circular Motion, Simple Harmonic Motion, and Universal Gravitation (Advanced Outcome)

Students will be expected to

- develop questions related to these topics (AP-09)

Fields (Advanced Outcome)

Students will be expected to

- apply Kirchoff's laws of voltage and current to circuits with two sources of emf (AP-11)

Waves and Modern Physics

Quantum Physics (Advanced Outcomes)

Students will be expected to

- explain the design and results of the Michelson-Morley experiment (AP-12)

- explain how Einstein developed the special theory of relativity, and its implications (AP-13)
- explain qualitatively thought experiments on spontaneity and time dilation (AP-14)

Literature Search and Report

Advanced Physics 11

Students will be expected to

- develop and explain a time line of light (AP-01)
- outline the past/present scientific discoveries and match with the time line (AP-02)

Advanced Physics 12

Students will be expected to

- collect, organize, edit, and present a summary of current information related to a specific topic (AP-03)
- write a report as a formal research paper (AP-04)

Investigation: An Independent Study/ Experiment

Advanced Physics 11

Students will be expected to

- gain information through modelling and guidance on the processes involved in scientific research and development (AP-05)
- construct a hands-on, self-directed experience and generate a report for public presentation (AP-06)

Advanced Physics 12

Students will be expected to

- collaborate and investigate on an independent research project (AP-07)
- maintain a research log, including personal reflection and data collection (AP-08)
- use technology and other skills effectively to communicate their results publicly (AP-10)

Attitudes Outcomes

It is expected that the Atlantic Canada science program will foster certain attitudes in students throughout their school years. The STSE, skills, and knowledge outcomes contribute to the development of attitudes; and opportunities for fostering these attitudes are highlighted in the Elaborations—Strategies for Learning and Teaching section of each unit.

Attitudes refer to generalized aspects of behaviour that teachers model for students by example and by selective approval. Attitudes are not acquired in the same way as skills and knowledge. The development of positive attitudes plays an important role in students' growth by interacting with their intellectual development and by creating readiness for responsible application of what students learn.

Since attitudes are not acquired in the same way as skills and knowledge, outcome statements for attitudes are written as key-stage curriculum outcomes for the end of grades 3, 6, 9, and 12. These outcome statements are meant to guide teachers in creating a learning environment that fosters positive attitudes.

The following pages present the attitude outcomes from the pan-Canadian *Common Framework of Science Learning Outcomes K to 12* for the end of grade 12.

Key-Stage Curriculum Outcomes: Attitudes

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

Appreciation of Science	Interest in Science	Scientific Inquiry
436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not **437** appreciate that the applications of science and technology can raise ethical dilemmas **438** value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds *Evident when students, for example,* • consider the social and cultural contexts in which a theory developed • use a multi-perspective approach, considering scientific, technological, economic, cultural, political, and environmental factors when formulating conclusions, solving problems, or making decisions on STSE issues • recognize the usefulness of being skilled in mathematics and problem solving • recognize how scientific problem solving and the development of new technologies are related • recognize the contribution of science and technology to the progress of civilizations • carefully research and openly discuss ethical dilemmas associated with the applications of science and technology • show support for the development of information technologies and science as they relate to human needs • recognize that western approaches to science are not the only ways of viewing the universe • consider the research of both men and women	**439** show a continuing and more informed curiosity and interest in science and science-related issues **440** acquire, with interest and confidence, additional science knowledge and skills using a variety of resources and methods, including formal research **441** consider further studies and careers in science- and technology-related fields *Evident when students, for example,* • conduct research to answer their own questions • recognize that part-time jobs require science- and technology-related knowledge and skills • maintain interest in or pursue further studies in science • recognize the importance of making connections between various science disciplines • explore and use a variety of methods and resources to increase their own knowledge and skills • are interested in science and technology topics not directly related to their formal studies • explore where further science- and technology-related studies can be pursued • are critical and constructive when considering new theories and techniques • use scientific vocabulary and principles in everyday discussions • readily investigate STSE issues	**442** confidently evaluate evidence and consider alternative perspectives, ideas, and explanations **443** use factual information and rational explanations when analysing and evaluating **444** value the processes for drawing conclusions *Evident when students, for example,* • insist on evidence before accepting a new idea or explanation • ask questions and conduct research to confirm and extend their understanding • criticize arguments based on the faulty, incomplete, or misleading use of numbers • recognize the importance of reviewing the basic assumptions from which a line of inquiry has arisen • expend the effort and time needed to make valid inferences • critically evaluate inferences and conclusions, cognizant of the many variables involved in experimentation • critically assess their opinion of the value of science and its applications • criticize arguments in which evidence, explanations, or positions do not reflect the diversity of perspectives that exist • insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position taken can be judged • seek new models, explanations, and theories when confronted with discrepant events or evidence

Key-Stage Curriculum Outcomes: Attitudes

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

Collaboration	Stewardship	Safety
445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *Evident when students, for example,* • willingly work with any classmate or group of individuals, regardless of their age, gender, or physical and cultural characteristics • assume a variety of roles within a group, as required • accept responsibility for any task that helps the group complete an activity • give the same attention and energy to the group's product as they would to a personal assignment • are attentive when others speak • are capable of suspending personal views when evaluating suggestions made by a group • seek the points of view of others, consider diverse perspectives, and accept constructive criticism when sharing their ideas or points of view • criticize the ideas of their peers without criticizing the persons • evaluate the ideas of others objectively • encourage the use of procedures that enable everyone, regardless of gender or cultural background, to participate in decision making • contribute to peaceful conflict resolution • encourage the use of a variety of communication strategies during group work • share the responsibility for errors made or difficulties encountered by the group	446 have a sense of personal and shared responsibility for maintaining a sustainable environment 447 project the personal, social, and environmental consequences of proposed action 448 want to take action for maintaining a sustainable environment *Evident when students, for example,* • willingly evaluate the impact of their own choices or the choices scientists make when they carry out an investigation • assume part of the collective responsibility for the impact of humans on the environment • participate in civic activities related to the preservation and judicious use of the environment and its resources • encourage their peers or members of their community to participate in a project related to sustainability • consider all perspectives when addressing issues, weighing scientific, technological, and ecological factors • participate in social and political systems that influence environmental policy in their community • examine/recognize both the positive and negative effects on human beings and society of environmental changes caused by nature and by humans • willingly promote actions that are not injurious to the environment • make personal decisions based on a feeling of responsibility toward less-privileged parts of the global community and toward future generations • are critical-minded regarding the short- and long-term consequences of sustainability	449 show concern for safety and accept the need for rules and regulations 450 be aware of the direct and indirect consequences of their actions *Evident when students, for example,* • read the label on materials before using them, interpret the WHMIS symbols, and consult a reference document if safety symbols are not understood • criticize a procedure, a design, or materials that are not safe or that could have a negative impact on the environment • consider safety a positive limiting factor in scientific and technological endeavours • carefully manipulate materials, cognizant of the risks and potential consequences of their actions • write into a laboratory procedure safety and waste-disposal concerns • evaluate the long-term impact of safety and waste disposal on the environment and the quality of life of living organisms • use safety and waste disposal as criteria for evaluating an experiment • assume responsibility for the safety of all those who share a common working environment by cleaning up after an activity and disposing of materials in a safe place • seek assistance immediately for any first-aid concerns like cuts, burns, or unusual reactions • keep the work station uncluttered, with only appropriate lab materials present

Learning and Teaching Advanced Physics: In-depth Treatment

Advanced Physics 11

Kinematics

- use vectors to represent position, displacement, velocity, and acceleration (325-5)

Even in this computerized world, engineers frequently use the power of diagrams to represent quantities and simplify solutions of complex problems. A good vector diagram is a scaled diagram, not a rough sketch. Throughout Advanced Physics 11 and Advanced Physics 12, there are many opportunities to do complete solutions using scaled vector addition and subtraction diagrams. Students who understand the graphic approach are more likely to understand more abstract algebraic solutions.

- identify and investigate questions that arise from practical problems/issues involving motion (212-1)

Making connections to experience is a practice that should continue throughout the course. Students could be asked to list motions they have knowledge of or experience with. In class discussion, these could be explored, and the teacher might point out which ones they will learn more about in their study of physics. From sub-atomic physics to vehicle collisions to rocketry to orbiting bodies, all have been studied by first exploring their motion. What about common experiences such as lightning, sound, and echoes, even water pouring from a tap?

- analyse word problems, solve algebraically for unknowns, and interpret patterns in data (325-2)

It is important to develop habits of analysis, inference, and organization in problem solving. This does not come naturally to many intuitive people, who want to rush to the solution. The best way to teach problem solving is to model it. Many students are not yet good at getting all the “hidden” facts such as that starting from rest means that initial velocity is zero. Taking the time to build a list or table of facts known and inferred is a good habit to have when problems become more challenging. Many problems can be approached with average velocity. For example if displacement is 50. m over 10. s of uniform acceleration, then the average velocity is 5.0 m/s. If the final velocity is 10. m/s, then the initial velocity was zero. Average velocity can be used as a primary solution or a quick check. See a sample of problems in Appendix A. Algebraic challenge: develop a formula to calculate the displacement in a specific second (for example the fifth second) of a uniform acceleration situation such as a free fall.

Momentum

- design an experiment, select and use appropriate tools, carry out procedures, compile and organize data, and interpret patterns in the data to answer a question posed regarding the conservation of energy (212-3, 212-8, 213-2, 214-3, 214-5, 214-11, 326-4)

This process should be reinforced by repetition throughout the course. It can be done as an individual assignment, a group task, or a whole-class exercise. For example, how could an investigation be conducted to determine what happens to momentum as mass is steadily lost by a moving object?

- analyse quantitatively the relationships among mass, speed, kinetic energy, and heat using the law of conservation of energy (326-1)

Throughout the mechanics section, it may be a good integrating activity to analyse collisions in the real world, where careful measurement and skilled interpretation go hand in hand. Beginning with in-line situations in Advanced Physics 11, the accident reconstruction theme can be continued in Advanced Physics 12. You may be able to get local police analysts to speak to the class and show the mathematics they use to analyse the aftermath of collisions. There are also thousands of websites. Check this one for skid mark treatment: www.harristechnical.com/articles/skidmarks.pdf

Cautionary Note: Police officers are trained in the use of field manuals that are handbooks in the application of specialized formulae. They are skilled technicians, but may be weak in the fundamental physics concepts. Students should be made aware of this before a speaker is used.

The optional extension mentioned on page 52 of the curriculum guide for Physics 11 and Physics 12 should be done by advanced physics students. This requires an understanding of both momentum and energy and can be done at another time. It is an excellent math link involving the use of a system of two equations to solve for both final velocities.

Work, Power, and Efficiency

- design and carry out an experiment to determine the efficiency of various machines (212-3, 213-2, 213-3, 214-7)
- apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions (326-3)

This activity is required for advanced physics students to analyse quantitatively the relationships among mass, speed, kinetic energy, and heat using the law of conservation of energy (326-1). Students should do an analysis of a real-world case such as a roller coaster, an airplane going from a standstill to stable level flight at 10 000 m, or the descent and landing of the space shuttle.

Waves: Sound Waves and Electromagnetic Radiation

- describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves (327-1)

After applying the properties to sound, students should do investigations to study the behaviour of light. They should do ray optics investigations of reflection, refraction, and image formation with plane and curved mirrors and convex lenses. The investigation of refraction in Advanced Physics 11 should examine both particle and wave explanations. The case of 0° incidence should get special attention. The predictions of both models regarding relative speeds in two media should be examined. Light diffraction and interference can be demonstrated with a laser. Students should develop a formula for determining the wavelength of the water waves that produce an interference pattern and apply it to a version of Young's experiment determining the wavelength of light. This discussion will continue in Advanced Physics 12.

Note: The sequence preferred by many teachers in this section would be

a) light behaviour
b) the particle explanation of light
c) the wave explanation of light

This sequence allows the teacher to follow a historical pattern and gives students an opportunity to experience how the development of physical and conceptual models is involved in the advancement of science. It sets up students for a more refined explanation in the modern physics section of Advanced Physics 12. Teachers with a separate class of Advanced Physics 12 may wish to use this sequence. Teachers with a combined Physics 12/Advanced Physics 12 class may wish to follow this sequence with both streams, while providing appropriate enrichment for the advanced group.

The waves and optics section offers a wealth of opportunity to explore the connections among science, technology, society, and the environment. From the Renaissance to the present, a pageant of fascinating characters have been engaged in the study of cosmology and the nature of light. The two were inextricably linked by the technology of the telescope and other optical devices that were the tools that allowed them to see farther and more clearly and, ultimately, to understand the position of man and planet Earth in the universe. There is no better unit to catch students up in the vastness of the study of physics and the fascination and wonder that so many of its students have expressed, from Leonardo da Vinci to Carl Sagan.

There is also no better unit in which to emphasize reading and writing skills. The history and philosophy of science are a vital humanizing link that advanced physics students, in particular, should be exposed to to help them know their place as they go on to further study. Using teaching techniques such as literature review, book reports, oral presentations, debates, and media presentation, students should learn more about the "who, where, when, and why" of science, as well as the "what."

Advanced Physics 12

Dynamics Extension

- use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques (ACP -1)

Vector addition and subtraction, especially with three or more vectors, are difficult concepts for some students. It is important that students are able to visualize the vectors acting on a single point. The addition of more than two displacement vectors and the addition of a boat's maximum speed relative to the water, the wind speed, and the current are examples included in the sample problems. It is strongly recommended that students do a scaled-diagram solution for a number of problems to help them see what vectors they are actually adding. Only then can they appreciate how the component method or the oblique triangle method work. Besides being useful to those students who go on to engineering, a quick vector diagram to approximate scale can help students estimate and check their final solutions.

At first, students may find this distinction too subtle and of little use, since most problem solving is in an Earth-bound inertial frame. This is, however, one of the key notions that led Einstein to the general theory of relativity. It is also a useful concept in the study of universal gravitation.

When a balance is used to find the mass of an object, the pull of gravity on the unknown object is compared to the force on gravity on a known object. If this balance were taken to the International Space Station, it would be useless, since there is no net gravitational force. From Newton's second law we know that

$$m = \frac{\vec{F}}{\vec{a}}$$

Any situation could be set up to accelerate an object of unknown mass. It could be a linear pull by a constant force or an oscillation. The result is called the inertial mass because it is a measure of the inertia, or resistance to motion, of the object. Gravitational mass and inertial mass are equivalent, but distinct, concepts. (See Giancoli, *Physics*, 5th ed., p. 1011.)

Projectiles

- analyse quantitatively the horizontal and vertical motion of a projectile (325-6)

While vector subtraction is not emphasized in Physics 11 and 12, it is important that advanced physics students have sound visual and mathematical understanding of this concept. Students should do a scaled vertical position versus horizontal position diagram. On this, they should draw vectors scaled to represent the horizontal and vertical velocity components at each tenth of a second. This should be done for both a horizontal projectile and a surface-to-surface projectile. Then the instantaneous velocity can be determined by draw-in as a head-to-tail vector addition and confirmed by mathematics. Finally, one instantaneous velocity can be subtracted from another at least 0.20 s later. Although the process is tedious, it is powerful evidence that gravity is the only significant force acting on the object in projectile motion.

Formulae for maximum range, maximum height, and time in the air should be explored. It is a good time to learn how to manipulate simple expressions to develop specialized equations.

The study of projectile motion provides another opportunity to relate physics formulae to mathematical expressions. Math students will have studied quadratic functions earlier and can benefit by a look back.

Circular Motion, Simple Harmonic Motion, and Universal Gravitation

- develop questions related to these topics (AP-09)

There has always been debate over the best sequence in the treatment of these concepts. Many teachers prefer to treat simple harmonic motion last. Using the circular analogue to explain simple harmonic motion (SHM) is an excellent way to show the kinds of problems that led to the development of the calculus. Universal gravitation is also a math-rich topic. The relation between circles and ellipses make for a good math challenge. In 2006, Pluto was demoted from planetary status, and a spaceport was proposed for Cape Breton. These are but two examples of the kind of media events that lead to student research and debate. Although dismissed in the media as whimsy, the spaceport location in Cape Breton has some practical advantages and requires no government funding.

The interplay of physics and mathematics, the experimental and the theoretical, is an enduring theme in the history of mankind, which started with Stone-Age musings about the night sky. It is very much a chicken-and-egg story, but very often a scientific hypothesis that has driven developments in mathematics. While we may have satisfactorily described and explained planetary motions, our understanding of the origin of the universe is by no means clear. Our increasingly complex description of subatomic structure and the relation between matter and energy are still a very open question. Will there be a grand unified theory that connects the four fundamental forces? Will new super-colliders answer our questions or open more? This is not the time to celebrate what we have mastered. This is the time to show students the breadth of the study of physics and the possibility that they can make a contribution.

Fields

- apply Kirchoff's laws of voltage and current to circuits with two sources of emf (AP-11)

The optional circuits section in the Physics 12 curriculum should be done in advanced physics. Specifically, students should develop a thorough understanding of potential difference in a field and in a circuit. Students should investigate Ohm's law experimentally and apply it to series, parallel, and simple network circuits. Kirchoff's laws of voltage and current in a circuit should be examined. (See Giancoli, pp. 564–68.)

Quantum Physics

- explain the design and results of the Michelson-Morley experiment (AP-12)
- explain how Einstein developed the special theory of relativity, and its implications (AP-13)
- explain qualitatively thought experiments on spontaneity and time dilation (AP-14)

Unit 7 in *McGraw-Hill-Ryerson Physics* begins with chapter 17, The Special Theory of Relativity. This is an excellent beginning for advanced physics students in that it deals with problems with the speed of light. The following outcomes should be done before outcome 326-7 in the Physics 12 guide.

Investigations and Experiments

The investigations and experiments component is an important aspect of any scientific study. A student enrolled in advanced physics is expected to complete the required investigations. The investigations should include, but not be limited to, the following:

Advanced Physics 11	Required Investigations and Experiments	Extensions
	• uniform acceleration of a falling object • friction (static and kinetic) • conservation of momentum • energy conversion (falling object) with motion probe • ballistic pendulum • resonance tubes • water wave interference • refraction and reflection with mirrors and lenses • diffraction/Young's experiment with laser or light box	Potential topics that are closely related or are extensions of an elaboration for students to design their own investigation include the following: • coefficient of friction • sound intensity • measure energy transfer (work, potential energy, kinetic energy) • Doppler-Fizeau • lenses All students must successfully design their own investigations.
Advanced Physics 12	• inclined planes with friction • electric-magnetic fields • projectile motion • radioactive decay • circular motion • circuit analysis • simple harmonic motion • two-dimensional collisions • mapping electromagnetic fields	Potential topics for students to design their own investigation include the following: • friction on ramps • projectile motion • simple harmonic motion • static electricity—rating of substances • measure electric field intensity • magnetic fields • radioactivity (background levels or levels in particular items) All students must successfully design their own investigations.

Literature Search and Report

A literature search and report are required part of advanced physics. This can take many forms and can be reported in a variety of ways. Students, like scientists, need to be able to effectively communicate their knowledge and findings to a variety of audiences in order to compare results, ask for funding, and/or write proposals and articles.

Advanced Physics 11

Outcomes

Students will be expected to

- develop and explain a time line of light (AP-01)
- outline the past/present scientific discoveries and match with the time line (AP-02)

Tasks for Instruction and/or Assessment

Journal

- Write a newspaper article that describes the historical applications of a curriculum concept.
- Comment on the following: Science is a ladder of knowledge. In order for modern discoveries to occur, scientists must be well aware of past developments.

Paper and Pencil

- Prepare a written report that profiles your research.

Resources

Books

- *Six Roads from Newton*
- *The Five Biggest Ideas in Science*
- *Heisenberg Probably Slept Here*

Websites

- Institute of Physics: Careers: Schools & Colleges **www.iop.org/activity/careers/Careers_Schools_and_Colleges/page_25768.html**
- Institute of Physics: Careers & Beyond **www.iop.org/activity/careers/Careers_University_and_Beyond/Students/index.html**
- APS Careers in Physics **www.aps.org/jobs**

Advanced Physics 12

Outcomes

Students will be expected to

- collect, organize, edit, and present a summary of current information related to a specific topic (AP-03)
- write a report as a formal research paper (AP-04)

Elaborations—Strategies for Learning and Teaching

Students are expected to explore the historical development of physics concepts and ideas as related to current studies.

Students are expected to examine the role of physics in the world around them. The exploration should include Internet research, periodicals research, and library research. Possible topics include

- imaging technologies
- hospital technologies
- forensics
- physical geology
- remote sensing
- engineering
- materials research
- aeronautics
- astronauts
- kinesiology

Tasks for Instruction and/or Assessment

Possible topics for research include the following:

- dark matter
- particle accelerators
- nuclear weapons
- string theory
- theory of relativity
- gravity waves
- neutrinos
- unified force theory
- antimatter
- organic light-emitting diodes
- development of measurement systems
- current research in magnetism
- current research in electric fields
- current research in particle physics

Resources

Books

- *The Five Biggest Ideas in Science*
- *Heisenberg Probably Slept Here*

Investigation: An Independent Study/Experiment

Outcomes

Advanced Physics 11

- gain information through modelling and guidance on the processes involved in scientific research and development (AP-05)
- construct a hands-on, self-directed experience and generate a report for public presentation (AP-06)

Advanced Physics 12

- collaborate and investigate on an independent research project (AP-07)
- maintain a research log, including personal reflection and data collection (AP-08)
- use technology and other skills effectively to communicate their results publicly (AP-10)

Introduction

A key component of the curriculum for advanced physics courses is the completion of a major culminating project that includes an extensive physics analysis.

The project creates an opportunity for students to explore physics from their own perspective. Through project-based science, teachers free their students to explore physics in ways that can incorporate in their research their backgrounds, skill sets, and interests. It allows students to become *real* scientists and truly learn about physics in the world around them.

Physics and Problem/Project-Based Science

Problem/project-based science, often referred to as "real science," is a science instruction method that has students and teachers completing projects in a fashion similar to the research methods of "real" scientists. Through individual and collaborative research, students are provided with the opportunity to construct science knowledge through hands-on, minds-on, self-directed experiences.
The problem/project-based method encourages teachers and students to explore and examine a variety of different activities and situations that address different learning styles and cognitive strengths. Through this process a number of science curriculum outcomes are easily addressed, as well as outcomes from other curriculum programs.

A problem/project-based science activity can be designed to fit any science classroom. It can be a small activity that covers a few class periods to a full-course investigation that results in a project to be celebrated in a variety of ways. Whatever the end result, problem/project-based science activities all include a number of common components. These are:

- *A focus question or hypothesis:* When students create a hypothesis or focus question they become the key figure(s) in a project from the beginning. A clear focus question allows organization of the method that will be used to direct the research. The question is key here and is one of the most difficult parts of the process. The focus question also provides a reference point for reflection throughout the study. The question may be revised throughout the course of study as directed by the research.
- *Investigation:* In project-based science the focus question leads directly to authentic problem solving through textual and online research, experimental design and operation, data collection and analysis, estimation, discussion and debate, group interaction, summarizing and drawing conclusions, and the refining and examination of the original question.
- *Artifacts:* Throughout the duration of a project, artifacts will be produced such as a number of reports, devices, and displays that show a true understanding of the focus question.
- *Collaboration:* Whether working alone or in groups, collaboration will occur throughout a project-based exercise. Working in class, sharing new discoveries, questioning others' conclusions, and participation in classroom presentations allow students and teachers to explore avenues in their research that they may not follow on their own, and further expand the study of the focus question.
- *Technology and Telecommunications:* Modern technology allows exploration science in a wide variety of ways. Communication with professional scientists, discussions with other students from around the region or the world, and the accessibility of vast amounts of information allow students and teachers to completely explore the answers to their questions and share the information that they have collected.

How to Use Project-Based Science

Project-based science can be used to cover virtually any topic in the science classroom. It allows the teacher to cover a variety of skills and social outcomes that are not always reached by traditional methods of science instruction. Project-based science should be used to bring the process of science (inquiry, problem-solving, and decision-making) to students. A project should include a discussion to establish focus questions, a specific time line for research and time for investigation. Creating a time line and a bank of resources will make projects run smoothly. A well-planned project that is presented with enthusiasm will be sure to cover a number of science outcomes.

Finding a Focus Question

The focus question is the most important part of a student and teacher project. Spending time on instruction of focus question development will pay off with better project results for your students. When creating a focus question, students should consider the following:

- Is the question interesting?
- Can the focus question be answered with the resources available for research?
- Does the focus question fit within the parameters set out for the project?
- Is the focus question clearly posed?
- Does the focus question clearly direct research?
- Can the focus question be completely investigated within the time line of the research?

A student or teacher should answer yes to all of the questions above. The focus question will be the driving force of research, so should be considered carefully.

The benefit to students of a clear focus question is the fact that it directs research along one specific pathway. Many students find long-term projects difficult because they find the amount of information available to be immense. If a clear focus question is developed before the start of in-depth research, the student will have less difficulty with the massive amounts of information available on any topic. The focus question allows students to quickly sort through useful and non-useful information.

Sample Teacher Project

The teacher project provides a teacher with a unique opportunity to guide student efforts without controlling the direction or methodology of student research. The teacher is always one step ahead of the student and uses the project to highlight where a student should be with their research as time passes. The teacher project also provides teachers to look into a specific aspect of the curriculum that may not otherwise be explored.

Benefits of Project-Based Learning

Project-based science provides a number of unique learning opportunities that are not found in traditional lecture and laboratory science classrooms. Treating students like “real” scientists turns the table on science learning and makes the student the constructor of knowledge. Some of the many benefits of a project-based approach to science instruction are

- the achievement of a number of STSE and science skills outcomes
- the achievement of a number of language arts outcomes with respect to writing
- the achievement of a number of mathematics outcomes
- the development of authentic learning and assessment practices
- the transfer of knowledge development from teacher to student

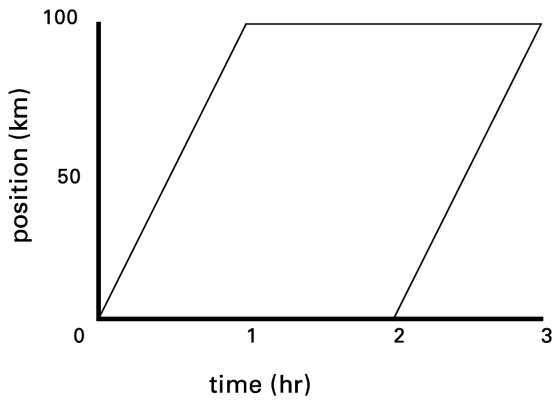
- the opportunity for teachers to become the students and develop project skills along with students
- the correlation of knowledge from physics, biology, chemistry, and other branches of science
- the development of problem-solving and questioning skills in students
- the opportunity to enhance research skills and develop critical-thinking and evaluation skills in students
- the opportunity for students to collect and share knowledge in a number of formats addressing a variety of intelligences
- the introduction of students to “real” science practices
- the opportunity for teachers in different curriculum areas to work collaboratively on a project.
- the ability to modify and adapt an individual’s project in order to accommodate their strengths and avoid weaknesses
- the chance to showcase student work to the school, to parents, and to the general public

Appendices

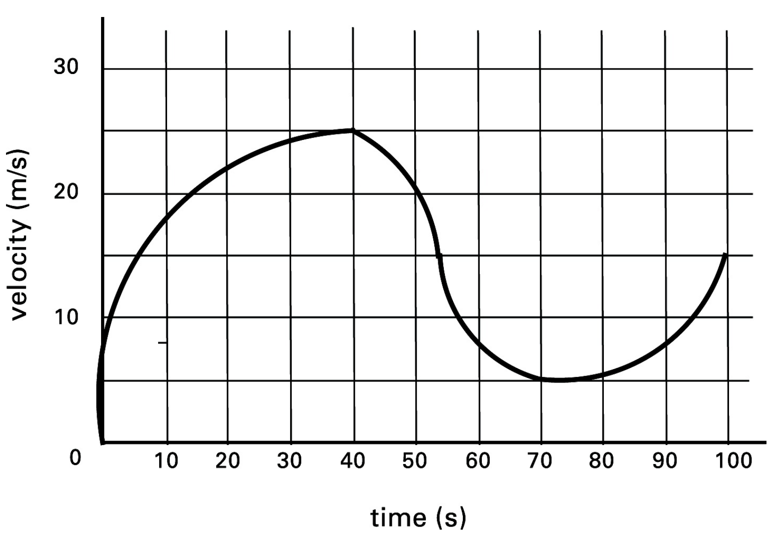
Appendix A: Problems for Advanced Physics 11

A set of sample problems that illustrate enrichment strategies follows.

1. Describe the motion shown on the following position vs. time graph.

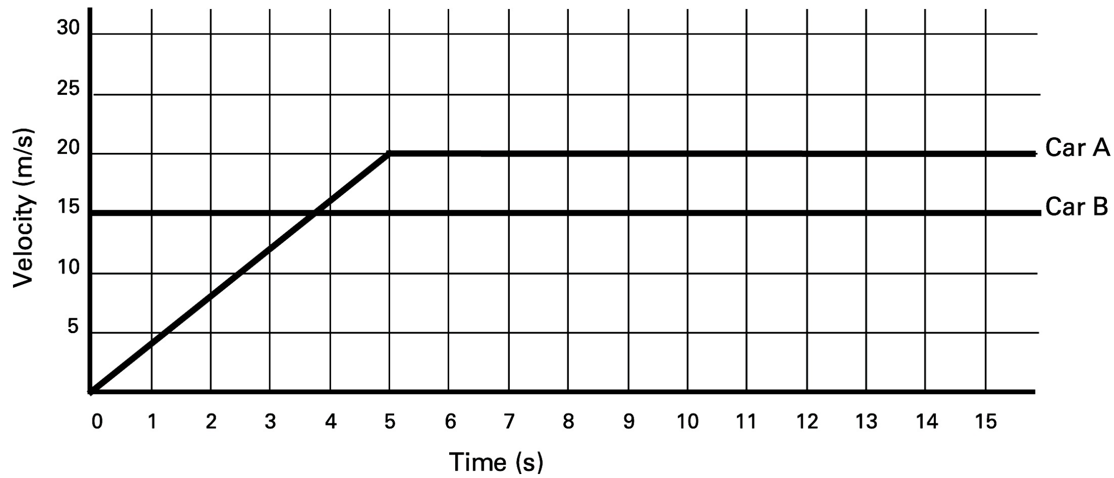


2. Construct the displacement vs. time graph that corresponds to the following velocity vs. time graph.



3. A pedestrian is running at his maximum constant speed of 6.0 m/s to catch a bus that is stopped at a traffic light. When he is 25 m behind the bus, it begins to pull away, accelerating at 1.0 m/s^2. Find out either at what time he catches the bus or what was the closest approach. Solve algebraically and with two position vs. time graphs on one grid.

4. The graph shows the velocities of two cars, A and B. Car A is stopped at a traffic light. Just as the light turns green and car A begins to accelerate, car B passes it going a uniform 15 m/s.



a) At what time is car A going the same speed as car B?
b) Which car is ahead, and by how much, at 5 seconds?
c) At what time will the two cars be the same distance away from the traffic light?

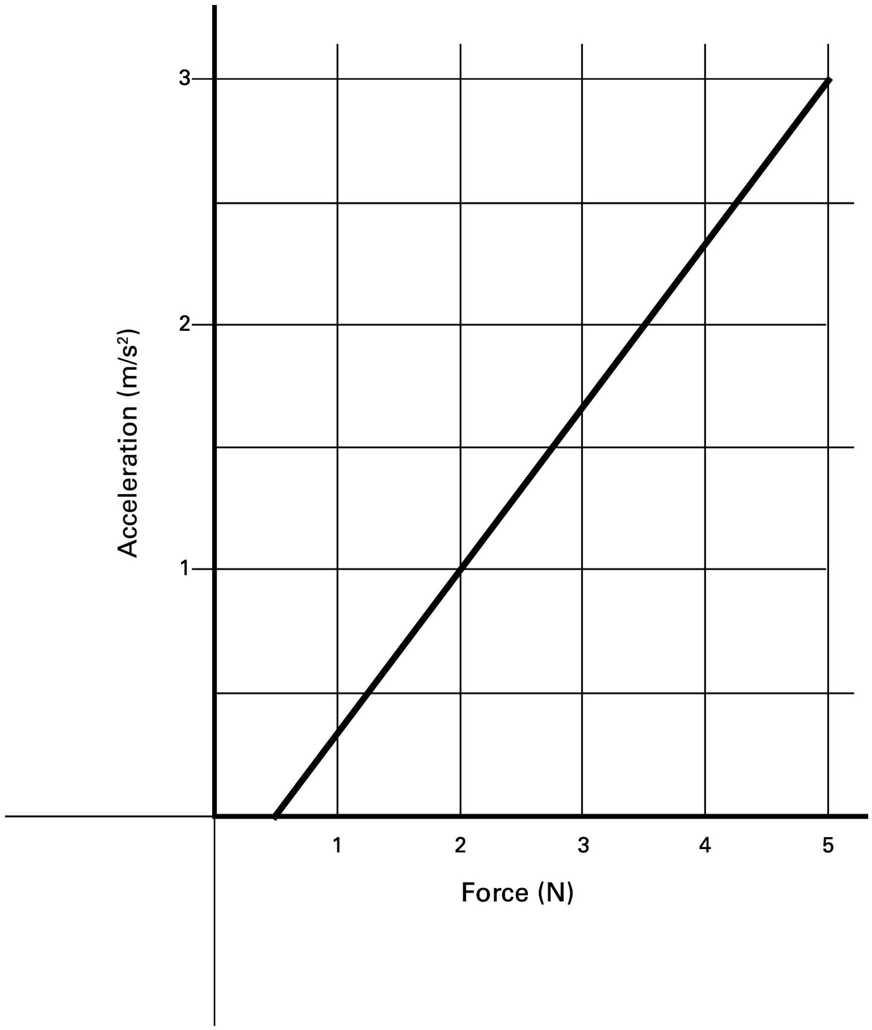
5. A block is moving along a smooth horizontal surface with a constant velocity of v_o at a time of t_o. A force of 18 N is applied to the block in the opposite direction to the motion. In the next 9.0 m of displacement, the velocity is reduced to half its original velocity.
a) How long does it take for this to occur?
b) What is the magnitude of v_o?

6. A student throws a ball against a wall and catches it on the rebound.
a) How many impulses were applied to the ball?
b) Which impulse was the largest?

7. A student is riding on a 20.0-kg cart that has a uniform velocity of 6.00 m/s. Consider the following situations when the student hits the ground. In each case, what is the change in velocity of the cart?
a) The student is moving at the same velocity as the cart.
b) The student is not moving relative to the ground.
c) The student is moving with twice the initial velocity.

8. A cart of mass 3 m and velocity v_o collides head on with a stationary cart of mass m. They stick together. How will the velocity after the collision (v_f) relate to v_o ?

9. A student conducts a number of trials applying different forces to the same mass wooden block. The graph is a record of the average forces and resulting accelerations.



a) What can you deduce from the fact that the graph is a straight line?
b) What does the intercept of the graph with the horizontal axis tell you?
c) Use the graph to predict the acceleration for a force of 3.5 N and 0.25 N.
d) If the experiment was repeated on a much rougher surface, what change would result in the graph?

10. A ball of mass m falls from a height h and compresses a vertical spring of force constant k a distance x. Ignore the mass of the spring. Develop an expression for the maximum compression (x) in terms of the other variables.

11. Compare the kinetic energies of two objects that are identical except for the following:
a) object A has twice the mass of object B
b) object A has twice the velocity of object B
c) object A is going north and object B is going south
d) object A has four times the mass and half the velocity of object B
e) object A is a projectile and object B is moving in a circle

12. Before you do any investigations into the nature of light, write the following essay.

    Suppose that you have been captured by aliens from the Planet of the Lightless Ones. They are creatures very much like yourself, except that they have no eyes and can in no way detect visible light. In the course of their examination of you, they discover the strange "flap-covered orbs" on your face and demand to know what they are for. You must explain the basic structure of the eye, the nature of light, and what practical value this has in your life. Answer thoroughly; your life may depend on it!

    Note: The intent of this activity is to have students explore their prior knowledge and stumble with trying to explain it. At the end of the course, students can be asked to do a similar writing assignment so they can "see" what they have learned.

13. You and a partner can explore the importance of binocular vision to our perception of depth. Each of you must cover one eye with a hand or other shield. One of you holds a pencil pointing up at waist height as far from your body as possible. The other should use another pencil pointing down to try and place the top pencil directly over the bottom pencil. Take turns trading places.

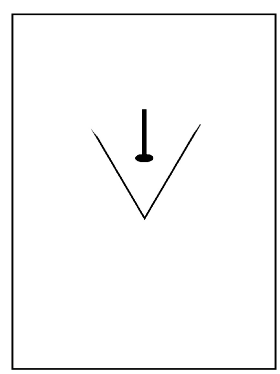
14. Evaluate both particle and wave explanations for the light behaviour you have seen so far. Which model do you think best explains the nature of light?

15. Two CF-18 supersonic military jets leave Winnipeg, headed in opposite directions in a race around the world (a distance of 40 000 km). The east-bound jet travels half its total flight distance at a speed of 2500 km/h, and the other half at 1000 km/h. The west-bound jet spends the first half of its flight time at 2500 km/h and the second half of its flight time at 1000 km/h. Which jet gets back to Winnipeg first, and how much time is it ahead of the other jet?

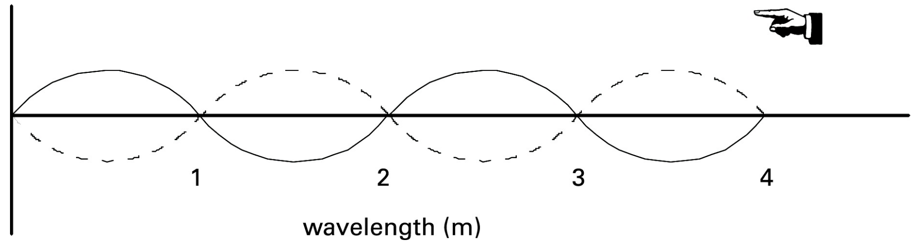
16. The air near the surface of the land or water is often a lower density than the rest of the air above. This results in optical illusions like mirages and what sailors call "looming." Draw a ray diagram to illustrate how this happens.

$$\lambda = \Delta x \frac{d}{L}$$

17. Set up two plane mirrors at a 60 ° angle as shown in the accompanying diagram. Stand a common nail on its head between the mirrors. Look carefully from side to side and count all the discrete images you can find. On a separate piece of paper, prove the location of each of these images by careful ray construction. (**Hint:** the di = do rule for plane mirror images may be helpful.)



18. The diagram below shows alternating loop positions in a standing wave in a helix.



a) What is the wavelength of the travelling wave that created this pattern?
b) How would the amplitude of the travelling wave compare to the apparent wavelength on this standing wave?
c) If the frequency of the oscillation is 4 Hz, what is the speed of the wave in the spring?

20. A subatomic particle called a meson is fired at a speed of 5.00×10^6 m/s into a region where an electric field causes a deceleration of 1.25×10^{14} m/s^2.
a) How long does it take to stop the meson?
b) How far does the meson travel while it is being stopped?

21. A 2.5-kg mass is moving at a constant speed of 3.0 m/s on a frictionless horizontal surface. It strikes a horizontally mounted spring bumper that has a force constant of 120 N/m. Determine the speed of the mass when the spring is compressed 0.25 m.

22. Suppose you are riding on a skateboard with a speed of 8.0 m/s. Your mass is 10 times the mass of the skateboard. Consider three ways to get off the board:
a) so that your horizontal speed stays the same
b) so that your horizontal speed changes to 4.0 m/s in the same direction
c) so that your horizontal speed changes to 10.0 m/s in the same direction
Determine the final velocity of the skateboard in each situation.

Appendix B: Problems for Advanced Physics 12

Mechanics: Dynamics Extension

1. A ferryboat, whose speed in still water is 2.85 m/s, must cross a 260-m wide river and arrive at a point 110 m upstream from where it starts. To do so, the pilot must head the boat at a 45° upstream angle. What is the speed of the river's current?

2. The speed of a boat in still water is v. The boat is to make a round trip in a river whose current travels at speed u. Derive a formula for the time needed to make a round trip of total distance D if the boat makes the round trip by moving
   a) upstream and back downstream
   b) directly across the river and back
   We must assume $u < v$. Why?

3. A bicyclist can coast down a 4.0° hill at 6.0 km/h. The force of friction is proportional to the speed v so that $F_{fr} = cv$. The total mass is 80 kg.
   a) Find the average force that must be applied in order to descend the hill at 20 km/h.
   b) Using the same power as in (a), at what speed can the cyclist climb the same hill?
   (Hint: $P = Fv$)

4. A small mass m is set on the surface of a sphere, as shown below. If the coefficient of static friction is 0.60, at what angle would the mass start sliding?

5. A 1.2-kg mass and a 3.2-kg mass are attached by a massless rope hanging over a pulley. The two masses are initially 1.60 m above the ground, and the pulley is 4.0 m above the ground. What maximum height does the 1.2 kg object reach after the system is released from rest?

6. Calculate the net force required to topple a 60-kg retaining wall 3.0 m high and 1.2 m thick. Assume that the toppling force acts 1.5 m above the base and that the force exerted by the ground to resist toppling acts at the corner of the base.

7. A uniform 9.5-m long ladder of mass 18.0 kg leans against a smooth wall (so the force exerted by the wall is perpendicular to the wall). The ladder makes a 20° angle with the vertical wall, and the ground is rough.
   a) Calculate the components of the force exerted by the ground on the ladder at its base.
   b) Determine what the coefficient of friction at the base of the ladder must be if the ladder is not to slip when a 75-kg person stands three fourths of the way up the ladder.

8. A person wants to push a lamp (mass 9.6 kg) across the floor. Assuming that the person pushes at a height of 60 cm above the ground, the base is 10 cm, and the coefficient of friction is 0.20,
   a) determine whether the lamp will slide or tip over
   b) calculate the maximum height above the floor at which the person can push the lamp so it slides rather than tips

Projectiles

1. a) Show that the range R of a projectile, which is defined as the horizontal distance travelled when the final point is at the same level as the initial point, is given by the equation where v is the initial velocity of the projectile and Θ is the angle with the horizontal. (Hint: Use the trigonometric identity $\sin 2\,\Theta = 2 \sin \Theta \cos \Theta$)
   b) Assuming that the initial velocity is v, what angle will provide the maximum range?

2. Determine how much further a person can jump on the moon as compared to the Earth if the takeoff speed and angle are the same. The acceleration due to gravity on the moon is one-sixth what it is on the Earth.

3. A basketball leaves a player's hands at a height of 2.1 m above the floor. The basket is 2.6 m above the floor. The player likes to shoot the ball at a 35° angle. If the shot is made from a horizontal distance of 12.0 m and must be accurate to ±0.22 m (horizontally), what is the range of initial speeds allowed to make the basket?

4. A ball is thrown horizontally from the top of a cliff with initial speed vo. At any moment, its direction of motion makes an angle of Θ with the horizontal. Derive a formula for Θ as a function of time.

5. At what initial velocity would an object fired from the ground at a 45° angle travel the same distance as an object fired horizontally from a height of 3 m above the ground?

6. Consider the monkey and the hunter problem that was discussed in class. Show mathematically that the monkey will be hit if he drops at the same moment that the hunter fires at him.

Simple Harmonic Motion

1. A 1.0-kg mass vibrates according to the equation $x = 0.42 \cos 7.40t$ where x is in metres and t in seconds. Determine:
   a) the amplitude
   b) the frequency
   c) the total energy
   d) the kinetic energy and potential energy when $x = 0.16$ m

2. The cone of a loudspeaker vibrates in SHM at a frequency of 262 Hz. The amplitude at the centre of the cone is 1.5×10^{-4} m and at $t = 0$ $x = A$.
   a) What is the (position) equation describing the motion of the centre of the cone?
   b) What are the maximum velocity and maximum acceleration?
   c) What are the equations describing the velocity and acceleration as a function of time?

3. a) What is the equation describing the motion of a spring that is stretched 20 cm from equilibrium and then released, and whose period is 1.5 s?
   b) Sketch a displacement-time graph of the motion.
   c) What will be its displacement after 1.8 s?

4. Derive a formula for the maximum speed v of a pendulum bob in terms of g, the length L, and the angle of swing Θ.

Two-dimensional Collisions

1. A particle of mass m travelling with a speed v collides elastically with a target particle of mass 2m (initially at rest) and is scattered at 90°.
   a) At what angle does the target particle move after the collision?
   b) What are the particles' final speeds?
   c) What fraction of the initial kinetic energy is transferred to the target particle?

2. After a completely inelastic collision between two objects of equal mass, each having initial speed v, the two move off together with speed v/3. What was the angle between their initial directions? You may need some trig identities for this one.

Uniform Circular Motion

1. For a car travelling with speed v around a curve of radius r, determine a formula for the angle at which a road should be banked so that no friction is required.

2. If a curve with a radius of 60 m is properly banked for a car travelling 60 km/h, what must be the coefficient of friction for a car not to skid when travelling at 90 km/h?

3. A 1200-kg car rounds a curve of radius 65 m banked at an angle of 14°. If the car is travelling at 80 km/h, will a friction force be required? If so, how much and in what direction?

Universal Gravitation

1. Using Newton's law of universal gravitation, show that for any satellite in a circular orbit around the earth, the ratio R^3/T^2 is a constant. Find the value of this constant.

2. Use Kepler's second law to show that the ratio of the speeds of a planet at its near and far points from the sun is equal to the inverse ratio of the near and far distances: $v_n/v_f = d_f/d_n$.

3. a) Show that if a planet orbits very near the surface of a planet with period T, the density of the planet is $D=3\pi /G T^2$.
   b) Estimate the density of the Earth, given that a satellite near the surface orbits with a period of about 90 minutes.

Fields

1. Two charges, $-Q_o$ and $-3Q_o$, are a distance l apart. These two charges are free to move but do not because there is a third charge nearby. What must be the charge and placement of the third charge for the first two to be in equilibrium?

2. Two non-conducting spheres have a total charge of 850 μC. When placed 1.30 m apart, the force each exerts on the other is 28.5 N and is repulsive. What is the charge on each? What if the force were attractive?

3. An electron moving at 1% of the speed of light to the right enters a uniform electric field region where the field is known to be parallel to its direction of motion. If the electron is to be brought to rest in the space of 5.0 cm,
   a) what direction is required for the electric field?
   b) what is the strength of the field?

4. A voltmeter reads 500 V when placed across two charged, parallel plates. The plates are 2.0 cm apart. What is the electric field between them?

5. What potential difference is applied to two metal plates 0.500 m apart if the electric field between them is 2.50×10^3 N/C?

6. If an oil drop with too few electrons is motionless in a Millikan oil drop apparatus,
   a) what is the direction of the electric field?
   b) which plate, upper or lower, is positively charged?

7. A negatively charged oil drop weighs 8.5×10^{-15} N. The drop is suspended in an electric field intensity of 5.3×10^3 N/C.
   a) What is the charge on the drop?
   b) How many electrons does it carry?

8. A voltmeter indicates that the potential difference between two horizontal parallel plates is 135 V. The distance between the plates is 3.2 cm. If a negatively charged drop with a mass of $3.45 \text{ X } 10^{-16}$ kg is suspended between these plates,
   a) how many extra electrons are on this drop?
   b) which plate is positive?

9. An electron is accelerated horizontally from rest in a television picture tube by a potential difference of 25 000 V. It then passes through two horizontal plates 6.5 cm long and 1.3 cm apart that have a potential difference of 250 V. At what angle Θ, with respect to the original direction, will the electron be travelling after it passes between the plates?

Appendix C: Suggested Activities

Advanced physics is designed to encourage the exploration of physics through multiple formats. The program provides opportunities for students to explore the world around them through problems, readings, writing, and questioning.

Teachers might consider incorporating one or more of the following activities or any others of their own design. Students might be encouraged to collaborate with each other on the activities.

Advanced Physics 11

- design and construct
  - egg drop
  - mechanically powered cars
  - roller coaster
  - rocket launch
  - Rube Goldberg devices
  - simple machines
- trip with physics analysis
  - drag strip
  - ski hill
  - indoor rock climbing
  - beach
- car accident reconstruction (in one dimension)
- physics analysis of computer / video games / movies
- designing a game that incorporates physics principles or concepts
- Physics Olympics

Advanced Physics 12

- design and construct
  - wind/water generator
  - catapult
  - Rube Goldberg devices
  - cantilever
  - large-scale electric or magnetic field demonstrator
- trip with physics analysis
  - racetrack
  - power plant
  - carnival midway rides
- car accident reconstruction in two dimensions
- analysis of shuttle launch and hook-up with the International Space Station
- target practice
- physics analysis of computer / video games / videos
- designing a game that incorporates physics principles or concepts

Appendix D: Physics Formulas

KINEMATICS

$$\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t} \qquad \Delta\vec{d} = \left\{\frac{\vec{v}_f + \vec{v}_i}{2}\right\}\Delta t$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \qquad \Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\Delta t^2$$

$$v_f^{\,2} = v_i^{\,2} + 2\vec{a}\Delta\vec{d}$$

$$v = \frac{2\pi r}{T} \qquad a_c = \frac{v^2}{r}$$

DYNAMICS

$$\vec{F} = m\vec{a} \qquad \vec{F}_g = m\vec{g}$$

$$F_f = \mu F_N$$

$$\vec{F}_s = -k\vec{x} \qquad F_c = \frac{mv^2}{r} \qquad F_c = \frac{4\pi^2 mr}{T^2}$$

$$F_g = \frac{Gm_1m_2}{r^2} \qquad g = \frac{Gm_1}{r^2} \qquad k = \frac{r^3}{T^2}$$

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

$$\tau = r_\perp F$$

ELECTRICITY AND MAGNETISM

$$F_Q = k\frac{q_1q_2}{r^2} \qquad \left|\vec{E}\right| = \frac{kq_1}{r^2}$$

$$F_m = B_\perp IL \qquad F_m = qvB_\perp$$

$$\vec{E} = \frac{\vec{F}_Q}{q_t}$$

$$V = \frac{\Delta E_Q}{q}$$

$$P = IV \qquad \frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

MOMENTUM, ENERGY, AND POWER		QUANTUM AND NUCLEAR PHYSICS	
$\vec{p} = m\vec{v}$	$\vec{F}\Delta t = m\Delta\vec{v}$	$E_{K(\max)} = hf - W$	$E = mc^2$
$W = \vec{F}\Delta\vec{d}\cos\theta$	$E_K = \frac{1}{2}mv^2$	$E = \frac{-13.6eV}{n^2}$	$c = f\lambda$
$E_g = mg\Delta h$	$E_e = \frac{1}{2}kx^2$	$E_{photon} = \left\|E_f - E_i\right\|$	$p = \frac{h}{\lambda}$
		$E_{photon} = hf$	$\lambda = \frac{h}{mv}$

Mathematics

$$c^2 = a^2 + b^2 - 2ab\cos C$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Some Useful Information

acceleration due to gravity at the Earth's surface	**g** = 9.81 m/s^2
universal gravitation constant	**G** = 6.67 x 10^{-11} Nm^2/kg^2
Coulomb's law constant	**k** = 8.99 x 10^9 Nm^2/C^2
magnitude of the charge on an electron	1.60 x 10^{-19} C
1 electron volt	**eV** = 1.60 x 10^{-19} J
Planck's constant	**h** = 6.626 x 10^{-34} J/Hz or J•s
radius of Earth	6.38 x 10^6 m
radius of Earth orbit	1.4957 x 10^{11} m
mass of Earth	5.98 x 10^{24} kg
speed of light in vacuum	**c** = 3.00 x 10^8 m/s
atomic mass unit	**u** = 1.6605 x 10^{-27} kg
rest mass of an electron	9.109 x 10^{-31} kg
rest mass of neutron	1.008665 u = 1.6749 x 10^{-27} kg
rest mass of proton	1.007276 u = 1.6726 x 10^{-27} kg

Appendix E: Periodic Table

Periodic Table of Elements

Key: atomic number 1, H, hydrogen, average atomic mass* 1.01

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H hydrogen 1.01																	2 He helium 4.00
2	3 Li lithium 6.94	4 Be berylium 9.01											5 B boron 10.81	6 C carbon 12.01	7 N nitrogen 14.01	8 O oxygen 16.00	9 F fluorine 19.00	10 Ne neon 20.18
3	11 Na sodium 22.99	12 Mg magnesium 24.31											13 Al aluminum 26.98	14 Si silicon 28.09	15 P phosphorus 30.97	16 S sulfur 32.07	17 Cl chlorine 35.45	18 Ar argon 39.95
4	19 K potassium 39.10	20 Ca calcium 40.08	21 Sc scandium 44.96	22 Ti titanium 47.87	23 V vanadium 50.94	24 Cr chromium 52.00	25 Mn maganese 54.94	26 Fe iron 55.85	27 Co cobalt 58.93	28 Ni nickel 58.69	29 Cu copper 63.55	30 Zn zinc 65.39	31 Ga gallium 69.72	32 Ge germanium 72.61	33 As arsenic 74.92	34 Se selenium 78.96	35 Br bromine 79.90	36 Kr krypton 83.80
5	37 Rb rubidium 85.47	38 Sr strontium 87.62	39 Y yttrium 88.91	40 Zr zirconium 91.22	41 Nb niobium 92.91	42 Mo molybdenum 95.94	43 Tc technetium (98)	44 Ru ruthenium 101.07	45 Rh rhodium 102.91	46 Pd palladium 106.42	47 Ag silver 107.87	48 Cd cadmium 112.41	49 In indium 114.82	50 Sn tin 118.71	51 Sb antimony 121.76	52 Te tellurium 127.60	53 I iodine 126.90	54 Xe xenon 131.29
6	55 Cs cesium 132.91	56 Ba barium 137.33	57 La lanthanum 138.91	72 Hf hafnium 178.49	73 Ta tantalum 180.95	74 W tungsten 183.21	75 Re rhenium 186.21	76 Os osmium 190.23	77 Ir iridium 192.22	78 Pt platinum 195.08	79 Au gold 196.97	80 Hg mercury 200.59	81 Tl thallium 204.38	82 Pb lead 207.20	83 Bi bismuth 208.98	84 Po polonium (209)	85 At astatine (210)	86 Rn radon (222)
7	87 Fr francium (223)	88 Ra radium (226)	89 Ac actinium (227)	104 Rf rutherfordium (261)	105 Db dubnium (262)	106 Sg seaborgium (266)	107 Bh bohrium (264)	108 Hs hassium (269)	109 Mt meitnerium (268)	110 Ds darmstadtium (271)	111 Rg roentgenium (272)	112 Uub ununbium (277)	113 Uub ununtrium (282)	114 Uuq ununquadium (285)	115 Uub ununpentium (288)	116 Uuh ununhexium (289)		

Transitional Elements: groups 3–12

elements 112-116 have not been officially named yet

Inner Transitional Elements

Period															
8	Lanthanoids	58 Ce cerium 140.12	59 Pr praseodymium 140.90	60 Nd neodymium 144.24	61 Pm promethium (145)	62 Sm samarium 150.36	63 Eu europium 151.96	64 Gd gadolinium 157.25	65 Tb terbium 158.93	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.04	71 Lu lutetium 174.97
9	Actinoids	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium 237.05	94 Pu plutonium (244)	95 Am americium (243)	96 Cm curium (247)	97 Bk berkelium (247)	98 Cf californium (251)	99 Es einsteinium (252)	100 Fm fermium (257)	101 Md mendelevium (258)	102 No nobelium (259)	103 Lr lawrencium (262)

average atomic mass values in parenthesis is the mass of the most stable isotope

Appendix F: Physics Preparation

This document is intended to be a study guide for students enrolled in physics. It includes information about the design of the final cumulative evaluation and tips to help you prepare to write it.

Examination Frequently Asked Questions

How is the examination organized?

Your physics course was organized around a set of ***outcomes***, which are statements of the knowledge and skills you are expected to be able to demonstrate at the end of the course. The examination is based on a plan that allocates questions by topic according to the time allocated in the curriculum for each of the four broad areas

Physics 11		Physics 12	
Kinematics	18%	Force, Motion, Work, and Energy	55%
Dynamics	21%	Fields	21%
Momentum and Energy	37%	Waves and Modern Physics	12%
Waves	24%	Radioactivity	12%

The questions are also based on three levels of thinking:

Level 1 Knowledge
Level 2 Comprehension and Application
Level 3 Analysis, Synthesis, Evaluation

Algebraic problems are also designed in three levels, from those that require simple one-step solutions to those that require complex, multi-step solutions.

The content of the examination is the same each time it is administered, but with different questions, so that the whole curriculum is assessed over time.

How should I prepare for the examination?

Start now. The most effective way to prepare for the physics examination is to start from the beginning of the course. Make review notes daily. Review them weekly. Get clarification quickly from your teacher. If you do not work with what you have learned, you will have forgotten 50% to 80% within 24 hours. The more often you reread and reorganize your notes as the course progresses, the less you will have to "cram" just before the exam. Use **all** of your textbook. Read the introductory material for each chapter and the margin notes. Read the **Chapter Review** thoroughly. The textbook questions are grouped under five headings: **Knowledge, Inquiry, Communication, Making Connections, Problems for Understanding.** Do not limit yourself to those questions assigned by your teacher. Use the CD provided with the text and the website.

You can also develop your skills by looking for situations outside of class where your physics skills can be applied. Observe the world around you. Read newspaper and magazine articles. Identify the physics concepts that apply to what you read. This will make you more confident with exam questions that present physics concepts in different situations.

What will the exam be like?

The examination is printed in booklet format with a blue cover. There are three sections to the examination. The **selected response** section consists of 35 multiple-choice-format questions, each having four alternative responses. The alternatives are listed alphabetically. Your mark in this section is the sum of your correct answers. There is no penalty for incorrect answers. When you have made a choice, blacken a circle on an exam response form. Instructions for the use of the form will be in the booklet. The second part of the examination is called the **short-answer** section. The 15 questions in this section, worth two points each, require an algebraic solution. Solve each question in the space provided in the booklet, and code your answer onto the student response form as directed. The third part is called **constructed response**. In this section, you will be asked solve a more extensive problem or answer a written response question. The total value of this section is 35 points.

What should I bring to the examination?

In general, you should bring the same things you would normally use in class:

✓calculator
✓protractor
✓clear plastic ruler
✓several sharp HB pencils
You might also consider bringing a good eraser, spare calculator (or batteries), tissues, cough drops, highlighter, and a sweater.

Are there rules about the use of calculators?

You must have your own calculator; they may not be shared during the examination. Calculator memories must be cleared before the examination begins. If you are not sure how to do this, get help **before** the examination. Do not take the chance of leaving information in memory. If it is discovered by a supervisor during the examination, it will be considered cheating.

What is expected in the solutions to problems?

If you use a clear pattern in everyday work, that habit will serve you well for the examination.

In general, follow these steps.

1. List the known and unknown variables.
2. Draw a free-body diagram where appropriate.
3. State the formula you will use.
4. Reorganize the formula for the unknown variable.
5. Show the replacements with units.
6. Show the answer with units.
7. Write a complete sentence that clearly answers the question posed.

This format is for your benefit. Organized work is easier to check and retrace if a correction needs to be made. Little bits of algebra scattered around the page are hard for you to check and a challenge to mark. If you are organized and neat, you will get the maximum value for your work. Writing a complete sentence as a final step is a way for you to ensure that you have done the right thing. Go back to the wording of the problem and be sure.

What do markers look for in written responses?

The marker is looking for a clearly written, direct response to the question. It is surprising how many students **do not**, in fact, answer the question being asked. Be sure you understand what is required before you start to write. Be clear and straight-forward in your writing. Although every effort will be made to understand what you have written, you will not help your cause by burying what you know in extra words.

Preparation Tips

Review Time, Place, and Rules

- Post your exam schedule in a conspicuous place.

Create a Review Schedule

- Plan your time for the four weeks before the exam.
- Allocate time to create specific review notes for each unit in the curriculum.
- Divide review time into blocks according to the time allocated for each unit and the effort you feel each unit will need.
- Review tests and assignments.
- Schedule time to meet with your teacher to discuss things with which you need help.

Make Summaries and Outlines

- Separate major concepts from factual details.
- Review laboratory reports. Know the general procedure for each. Make sure you know the major concept to which each is connected.
- Think about real-world connections for each topic.
- Review graph plotting and analysing procedures.
- Ask your teacher for a copy of the formula sheet that will be provided at the examination. Become familiar with all possible rearrangements you might have to do and with situations in which two formulae can be equated, such as universal gravitation and centripetal force.

Develop Memory Aids

- Read key words aloud and state the meaning of each.
- For lists, number each item to help remember the sequence.
- Use sticky notes as margin tabs or make a concept map on poster board.
- Use a highlighter for emphasis. Using more than one colour may make sections more visually distinct and easier to remember.

Things to Do During the Examination

- **Plan to be comfortable:** Eat properly and get plenty of rest in the days before the examination. Wear comfortable, loose clothing. If you know what the temperature will be like in the room where the examination is written, dress appropriately. Take a bathroom break just before you write. Avoid last-minute conversations about the examination. Although this advice seems obvious, it is clear that many students do not follow it.

- **Be prepared:** Collect the things you need to bring on the day before the examination. Clear your calculator memory. Plan to arrive early.

- **Plan your time:** Scan the exam and budget your time using suggested time allocations as a guide. In the constructed response section, do the questions you are most sure of first. The questions are not arranged in order of difficulty, and you do not have to do them in order. Do not waste time pondering a difficult question if there are others you can do faster and better.

- **Answer every question:** There is no penalty for wrong answers on any part of the examination. Partial answers are often worth partial credit.

- **Summarize your answer:** For both written response questions and algebraic problems, be sure to conclude with a statement that clearly answers the question.

- **Be logical:** Identify key words. Multiple-choice questions with four possible responses often contain two alternatives that are easily eliminated. Look at the remaining alternatives carefully. Is there a further clue to the right answer? Is there a choice between opposites, such as positive or negative, up or down, north or south? Is there an exponent in the alternatives that you can compare with a power of 10 estimate of the answer? When you scanned the exam, did you notice if there was something in another part that might be helpful? Finally, if the solution to a multiple-choice question seems to require more than five minutes, there is probably a faster method. Flag this question and come back to it later.

- **Think about the marker:** The way you present your solutions and written responses tells the marker a lot about what you know and how well you can use that knowledge. If your presentation is confusing, the marker is led to believe that you lack understanding.

Appendix G: Key Directing Words

Compare	Point out only the similarities between two things being compared.
Contrast/Distinguish	Point out only the differences between two things being compared.
Conclude	Bring to a logical end. You may be asked to draw a conclusion based on what you have learned or based on information provided.
Define	Present clearly the meaning of a word or the essential qualities of a concept.
Describe	Provide a written summary of the characteristics of a specified item.
Design	Present a sequence of actions or steps that will achieve a desired goal (for example, how would you do an experiment to measure the acceleration of gravity?).
Evaluate	Indicate the good and bad (positive and negative) characteristics of some thing or event. Pay careful attention to any specific criteria against which your evaluation must be done.
Explain	Make clear using physics principles.
Illustrate	Make clear by providing an example.
Predict	Tell in advance based on trends in observed data.
Prove/Show	Support the truth of a fact or statement using evidence and logic.
Summarize	Give a brief account of the main points.
Trace	Give a step-by-step account of the development of a theory or technology.

Appendix H: Project-Based Science

What Is Project-Based Science?

Project-based science, often referred to as "real science," is a science instruction method that has students and teachers completing projects in a fashion similar to the research methods of "real" scientists. Through individual and collaborative research, students are provided with the opportunity to construct science knowledge through hands-on, self-directed experiences. The project-based method allows teachers the chance to examine students in a variety of different activities and situations that address a variety of different learning styles and cognitive strengths. Through this process, students cover a number of science curriculum outcomes as well as outcomes for other curriculum programs in which they are involved in on a daily basis.

A project-based science activity can be designed to fit any science classroom. It can be a small activity that covers a few classes a full course investigation that results in a project to be presented to the class, at a public presentation such as PTSA night, or in an electronic journal, or entered in a local or regional science fair. Whatever the end result, project-based science activities all include the following common components,

- **A focus question or hypothesis:** When students create a hypothesis or focus question, they become the key figure(s) in a project from the beginning. With a clear focus question, students can organize the methods that they will use to direct their research in order to arrive at an answer to their question. The focus question also provides students with a reference point for reflection throughout their study. The question may be revised throughout the course of study as directed by the students' research.

- **Investigation**: In project-based science the student's focus question leads directly into authentic problem solving through textual and online research, experimental design and operation, data collection and analysis, estimation, discussion and debate, group interaction, summarizing and drawing conclusions, and refining and examination of the original question.

- **Artifacts:** Throughout the course of a project, students will produce a number of reports, devices, and displays that show a true understanding of their focus question.

- **Collaboration:** Whether working alone or in groups, students will be collaborating with others throughout a project-based exercise. Working in class, sharing new discoveries, questioning others' conclusions, and participating in classroom presentations allow students to explore avenues in their research that they may not follow on their own and further expand the study of the focus question.

- **Technology and telecommunications:** Modern technology allows students to explore science in a wide variety of ways. Communication with professional scientists, discussions with other students from around the region or the world, and the accessibility of vast amounts of information allow students to completely explore the answers to their questions and share the information that they have collected.

Incorporating Project-Based Science in the Classroom

Project-based science is a rewarding method of instruction that allows students and teachers to interact in ways that are not common in traditional science classrooms. It is recommended that the teacher also does a project to model the behaviour with the students. By doing a project along with the students, the teacher has the control over time lines, the opportunity to lead by example, and the chance to assess and examine students exploring science with their classmates. Hands-on, minds-on science will be developed throughout the project.

The role of the teacher in a project-based science activity changes from a person who provides the knowledge to a person who facilitates research. The teacher models the processes expected of the students, makes suggestions on the direction of student research, and encourages students to follow their successes and explain their questions. This change in instructional method offers teachers an opportunity to examine the content of their courses in a different light and helps them prepare students to be students after high school.

Teachers must fully adopt the project-based science concept when completing an activity with their classes. The teacher changes from a person who asks questions to a person who facilitates the answering of questions. It is important for teachers to be aware of where their students are throughout the entire investigation. Teachers can guide the students' research without controlling the topics, methods, or focus questions just by being aware of the current status of each student's project.

Planning: The initial organization of a project-based science classroom can be time consuming and labour intensive; however, once the initial guidelines are established, this time becomes minimal for future project-based activities. When properly organized, a project-based activity will run smoothly and achieve its goals for all students, as well as provide a number of opportunities for student assessment. The following are some suggested steps for beginning a project-based activity in the classroom:

1. **Decide on the type of project.** Project-based learning can be used for short-term activities like exploring a specific topic in a unit or a complete unit. It may also be used for elaborating, long-term activities that students may use to summarize their learning in a course or use to compete in local or regional science fairs.

2. **Establish a time line for the project.** No matter what type of project is ongoing in a classroom, a well-defined and adhered-to time line for the activity is key to its success. When students are aware of the time expectations on them, they are less likely to fall behind. The teacher project and class time are important to help keep all students on task and to ensure that all are where they are supposed to be with their individual projects. A checklist can be created for teachers and students to keep track of their progress during the project. Some sample time lines can be found at the end of this section.

3. **Organize the teacher project.** Teachers must decide upon a project to carry out as a model for the students. By going step by step through a project with the class, a teacher will emulate the work habits expected of students as well as keep the class on time and on task. The chance to always be a week, a day, or an hour ahead of students allows the teacher to keep the student on task throughout the project.

4. **Determine the methods of evaluation that will be used.** Project-based science creates many opportunities for the evaluation of student work. If the value of the project in the overall marking scheme is clearly stated, students may be motivated to accept the challenge of a project and work hard to succeed. A clearly designed rubric should be created for updates and activities completed during project assessment, as well as a rubric for the culminating activity. Some sample rubrics can be found at the end of this section.

5. **Prepare a list of books or a website containing project ideas.** Once the format of a project has been determined, teachers should create a list of possible resources that will aid students in the beginning stages of a project.

6. **Establish cross-curricular links with other teachers.**
   Project-based science requires a wide variety of skills in order to be complete. Students will not only be meeting science outcomes through the project process, but will also cover language, art, mathematics, and other course outcomes. Teacher collaboration in the planning stage of a project will allow for a broad-based assessment of student projects.

7. **Establish mentorship links.** Professional or academic mentorships are a useful tool for students in long-term research. Arranging for student mentors before a project begins will assist in the initialization of a project and will provide students with someone to contact if questions come up through research.

8. **Organize a project showcase.** Presentation time and space should be allotted for students to showcase their project work. Booking a time and space well in advance will give the students a clear target date and give the projects a clear focus for the cumulating activity.

Keeping a Research Log

One of the best ways to keep a project running smoothly from start to finish is through the upkeep of a research log or journal. A research log that is kept up to date will allow students to look back at what they have done, examine and reflect upon results, and change the research direction of their future research. The research log should have two components that are kept up to date throughout the time of study.

The first part is the personal reflection on discoveries to date. Here students can examine what they have discovered, relate it to their current knowledge, and explore how it applies to their projects. The reflection also provides students with an opportunity to sort through the information they have collected and filter out the parts that do not relate to their focus question, thus making the end goal of their research more clear. The entries in the reflection section should all be dated in order for students and the teacher to keep up to date on the research time line.

The second part is the data. Regardless of whether the project is a study, an experiment, or an innovation, a student is going to collect data of one form or another. A well laid-out research log provides students with a place to collect, organize, and analyse their data. The end result of a project should contain a conclusion based on the data, but need not contain every piece of information collected throughout the course of study.

Research logs provide an excellent opportunity for students to assess their work to date and use this assessment to further develop their study. The logs also provide a teacher with a tool to assess how well the students worked on their project from start to finish.

A research log should be maintained from day one of a project until it is completed. Teachers may set up the format of the research log for their students, and all research logs should be organized in a way that fits the topic or method of study chosen by the student and teacher.

Sample Projects and Time Lines

The following pages contain some sample documents that you may use to set up project-based science in the classroom. The samples include rubrics, time lines, required math skills, and some resources available to teachers. Some of the examples are content specific, and others are generic ones that may be used as guidelines to set up individual investigations.

Section or Topic Project

Section or topic projects are short-term activities that are designed to quickly investigate a particular subject in a science classroom. This type of project allows students obtain some background information about a topic before the class completes a full investigation. These activities my be used to introduce a chapter or to summarize a recently completed topic area.

Time Line

Four one-hour periods will be set aside to complete the following project.

Period	Activity	Comments	Checklist
1	Introduction, class discussion, and topic research	Students should be given information about the topic that is being covered and the opportunity to explore and create focus questions.	By the end of the period all students will have a focus question for their research.
2	Focus question refinement and data collection	Students will review the focus question suggestions provided by the teacher and continue research with the focus question as the core of their research.	By the end of the period all students will have a complete focus question, an overview of the data they still need to collect, and a summary of the information collected so far.
3	Research completion	Students will finish their data collection and finalize plans for the presentation of their discoveries.	By the end of the period all students will have a summary of their discoveries and a description of the artifacts they will use to share the information with the class.
4	Project completion	Students will prepare the artifacts for the project.	By the end of the period all students will hand in a completed project report and artifacts.

Unit Project

An activity that may address all or part of a unit. The project may be used to cover topics that are more difficult to cover using traditional methods or to provide a variation from traditional science teaching methods.

Time Line

Nine class hours will be set aside over the next six weeks to complete and present the following project.

Period	Activity	Comments	Checklist
1	Introduction and topic research	Students should be given information about the topic that is being covered and the opportunity to explore and create focus questions.	By the end of the period, all students will have a rough draft of their focus question.
2	Focus question refinement	Students should share their focus questions with the teacher and other students and begin to outline their project design.	By the end of the period, all students will have a finalized focus question and an draft outline of their project design.
3	Research tools and project design	Students will begin their research by locating resources and creating a bibliography of sources they plan to use. Students will also finalize their project design.	By the end of the period, all students will have a completed project design and a list of five resources they will have on hand to research their focus question.
4	Research and experimental design and setup	Students will continue research into their focus question and, if appropriate, set up their experimental equipment in order to complete their study.	By the end of the period, all students will have a collection of data or summarized information that describes their focus question.
5	Continued research and experimentation	Students will continue with their research and data analysis.	By the end of the period, all students will have a record of collected data and what research has yet to be completed
6	Research completion	Students will conclude their research and data collection.	By the end of the period, all students will have completed all research and experimentation necessary to complete their project.
7	Project organization	Students will have all of the materials necessary to bring their project together as a cumulative reporting of their study. This may include papers, display posters, or a website.	By the end of the period, all students will have a completed project
8–9	Presentations	Students will present their projects to their teacher and their peers.	By the end of the period, all students will have presented to and/or evaluated the projects of their classmates.

Long-Term Project

A long-term project can address a multitude of science topics. A long-term project requires a lot of work both from the teacher and the students and should be valued to reflect its importance. As with any project-based science activity, the teacher should participate by completing a project with the students. This helps the students keep on task and interested in the work and provides the teacher the opportunity to demonstrate skills such as research methods, experimental design, and data collection, which are not always involved in traditional science teaching.

Time Line

One period of each Friday will be set aside for science project work. In the 16th week there will be an in school public presentation.

Time Line for Research

Week	Activity	Comments	Checklist
1	Introduction and topic research	Students should be given information about the topic that is being covered and the opportunity to explore and create focus questions.	By the end of the period, all students will have a rough draft of their focus question.
2	Focus question refinement and project design	Students should share their focus questions with the teacher and other students and begin to outline their project design.	By the end of the period, all students will have a finalized focus question and a draft outline of their project design.
3	Research tools and project design	Students will begin their research by locating resources and creating a bibliography of sources they plan to use. Students will also finalize their project design.	By the end of the period, all students will have a completed project design and a list of five resources they will have on hand to research their focus question.
4	Research list preparation	Students are to complete and pass in a list of resources and a description of how these resources will be applied to their research question.	By the end of the period, all students will have passed in a list of resources they plan to use in their study.
5	Project design completion	Students are to complete a concept map for their project with suggested time lines, necessary equipment and resource materials, and experimental or laboratory components.	By the end of the period, all students will have passed in a concept map with time lines for their project.

Week	Activity	Comments	Checklist
6–9	Research and experimentation	Students will carry out research and carry out experiments to evaluate their hypothesis and reassess their discoveries and predictions.	Students will maintain a data log in which they record their discoveries and refinements to their project.
10	Progress report	Students will be reminded that they are two thirds of the way through their projects will prepare progress reports.	By the end of the period, all students will have passed in a progress report that includes a summary of discoveries, changes to the project design, new resources, and a diagram or description of the display layout for the project.
11–12	Continued research and experimentation	Students will begin to finalize their projects by assessing the discoveries made to date and deciding what needs to be done to complete the project. Students will also correlate and analyse data collected.	Students will maintain a data log in which they record their discoveries and refinements to their project.
13	Report completion	Students will put the finishing touches on their written reports and prepare 50-word summaries of their discoveries.	By the end of the period, all students will have passed in their project reports and 50-word summaries.
14	Display completion	Students will put the finishing touches on their project displays and seek out advice from teachers and fellow students.	By the end of the period, all students will have passed in their completed project displays.
15	Project sharing	Students will set up their projects and share them with classmates in order to prepare for the science fair.	By the end of the period, students will be prepared to present their science fair projects.
16	Public presentation	Students will present their projects to judges, teachers, and the public.	By the end of the day, students will have presented effectively their project.

Assessment and Evaluation

The assessment of a project-based science activity provides teachers with a unique opportunity to evaluate student learning in science. There are a variety of STSE, scientific skill, and knowledge outcomes that may be covered through a project. Providing students with the opportunity to assist in the creation of evaluation tools for projects gives them an opportunity to examine how to design a project that fits the project they are working on.

Assessment of Learning

Assessment of learning is the method of evaluation that is most familiar to teachers. This type of assessment involves looking back at what students have covered and determining how well they have internalized the information. The completed project should represent the learning of students at all stages of project development. A good rubric or set of rubrics makes the assessment of a student project quick and effective to complete. Rubrics are useful tools in the final assessment of a physics project. Rubrics should include the assessment of all aspects of the student project, including focus question quality, research effectiveness, effort, and the overall quality of all artifacts produced through research.

Assessment for Learning

Assessment for learning involves the use of effective assessment tools to help develop knowledge through the act of assessment. A project-based investigation that includes clearly focussed assessment guidelines that involve students in all aspects of the assessment creates unique learning opportunities for both students and teachers. Students should be involved in the creation of rubrics, the creations of questions based on their research, and the evaluation of their work from start to finish. The chance to be part of the assessment of a project from start to finish empowers students and creates conditions that allow for them to capitalize on every learning opportunity provided by a project.

Rubrics

A complete scoring rubric, which addresses all aspects of a project, is one of the most effective and efficient ways to evaluate a project. A rubric can be developed with students and should be completed by both students and teachers throughout the course of a project. There are a number of online resources available to help with the creation of scoring rubrics for any project.

Example Scoring Rubric

Teacher name: Science Teacher

Student Name ___________________

CATEGORY	4	3	2	1
Idea	Independently identified a question that was interesting to the student and that could be investigated.	Identified, with adult help, a question that was interesting to the student and that could be investigated.	Identified, with adult help, a question that could be investigated.	Identified a question that could not be tested/investigated or one that did not merit investigation.
Hypothesis Development	Independently developed an hypothesis or focus question well substantiated by a literature review and observation of similar phenomena.	Independently developed an hypothesis or focus question somewhat substantiated by a literature review and observation of similar phenomena.	Independently developed an hypothesis or focus question somewhat substantiated by a literature review or observation of similar phenomena.	Needed adult assistance to develop an hypothesis or focus question or to do a basic literature review.
Description of Procedure	Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations. No adult help was needed to accomplish this.	Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations. Some adult help was needed to accomplish this.	Procedures were outlined in a step-by-step fashion, but had one or two gaps that require explanation even after adult feedback had been given.	Procedures that were outlined were seriously incomplete or not sequential, even after adult feedback had been given.
Data Collection	Data was collected several times. It was summarized, independently, in a way that clearly describes what was discovered.	Data was collected more than one time. It was summarized, independently, in a way that clearly describes what was discovered.	Data was collected more than one time. Adult assistance was needed to clearly summarize what was discovered.	Data was collected only once, and adult assistance was needed to clearly summarize what was discovered.
Conclusion-Summary	Student provided a detailed conclusion clearly based on the data and related to previous research findings and the hypothesis statement(s).	Student provided a somewhat detailed conclusion clearly based on the data and related to the hypothesis statement(s).	Student provided a conclusion with some reference to the data and the hypothesis statement(s).	No conclusion was apparent, OR important details were overlooked.
Student Participation	Student participated actively in the creation, development, and all research aspects of the project.	Student participated actively in parts of the project with which they feel comfortable.	Student participated periodically in the research aspects of the project.	Student did not participate in the development of the project.

Appendix I: Statistical Analysis for Science Projects

The following pages contain a list of mathematical skills that may be useful in completing a project-based science activity.

Mathematics and its branches form the foundation of all science. With numbers we can interpret physical, chemical and biological concepts. Scientists can also use numbers, in the form of statistics, to display information in a clear, easy-to-follow method that most people can read and interpret with relative ease. The following section is a basic introduction to some statistical methods that can be applied in scientific study.

Mean, Median, and Mode

The mean, median, and mode provide a simple set of numbers that provide very general information as to where the typical data for your study is. Using the statistics one can interpret how any data collected would fit in with the general trends.

A. **Mean**: the average of any set of data; calculated by summing all of the data samples and deciding the sum by the total number of samples. The mean is perhaps the most commonly used statistical value. It is useful because it includes all data points and can be used to calculate other statistical values. It is also well known as the **average** by the majority of people in the general population.

B. **Median:** the mid point of any set of data; calculated by arranging data in ascending order and finding the value that represents the point at which 50 percent of the samples are above a value and 50 percent are below a value. The median is generally used as a predominant statistic when the results of the study are skewed one way or another or when a sample is open ended or incomplete.

C. **Mode**: the most frequently occurring value in a data sample; useful in identifying trends and identifying clusters in the data.

Example

The following table contains a theoretical list of high temperatures recorded in degrees Celsius for the month of July.

Date	1	2	3	4	5	6	7	8	9	10	11
High Temp	**20**	**25**	**25**	**24**	**23**	**18**	**22**	**25**	**28**	**28**	**30**
Date	12	13	14	15	16	17	18	19	20	21	
High Temp	**31**	**31**	**28**	**27**	**25**	**22**	**17**	**22**	**25**	**20**	
Date	22	23	24	25	26	27	28	29	30	31	
High Temp	**21**	**25**	**26**	**24**	**22**	**20**	**22**	**24**	**28**	**26**	

A. **Mean:** $\frac{\text{sum of all temps}}{\text{\# days}} = \frac{754}{31} =$ **24.32°C**

B. **Median:** There are 31 data points, thus the middle data point will be the 16th point. As seen below, the 16th data point for our study is **25°C**

17-18-20-20-20-21-22-22-22-22-22-23-24-24-24-**25**-25-25-25-25-25-26-26-27-28-28-28-28-30-31-31

Note: If there are an even number of data points, the average of the two middle numbers represents the median.

C. **Mode:** The most frequently occurring high temperature is **25°C**. It occurs six times in the data.

Note: There may be more than one mode, if the data set has two values of equal frequency.

D. **Weighted Means:** If several different data sets with varying numbers of samples are being examined and the data is combined into one statistical set, the size of these samples must be accounted for. A weighted mean gives more weight over the entire data set to the larger samples.

To calculate a weighed mean you would use the following equation:

$$wm = \frac{n_1x_1 + n_2x_2 + n_3x_3 \ldots n_sx_s}{n_1 + n_2 + n_3 + \ldots n_x}$$

n = # data points in an individual sample
x = mean of data points in a sample
s = # sample sets

Example

Monthly mean daily high temps for summer

June:	n = 30 days	x = 17.25°C
July:	n = 31 days	x = 24.32°C
August	n = 31 days	x = 22.85°C

The weighted mean for the summer would be:

$$wm = \frac{[30*17.25] + [31*24.32] + [31*22.85]}{[30+31+31]} = 21.52°C$$

Standard Deviations

Standard deviations are statistics used to measure the variation in a set of data. They can be used to interpret the likelihood of a given result based on how far the value is away from the mean of the total data set. The standard deviation for a given set of data is equal to the square root of the arithmetic mean of the squares of the deviations from the arithmetic mean.

To calculate the standard deviation for our temperature data:

1. Subtract each data point from the mean and square the results

   Note: Values that occur more than once in a set of data must be counted for each occurrence.

17-18-20-20-20-21-22-22-22-22-22-23-24-24-24-**25**-25-25-25-25-25-26-26-27-28-28-28-28-30-31-31

Mean (μ) = 24.32

(Value - Mean)^2	result * number of occurrences	result
$(17-24.32)^2$ =	53.58 * 1 =	53.58
$(18-24.32)^2$ =	39.94 * 1 =	39.94
$(20-24.32)^2$ =	18.66 * 3 =	55.99
$(21-24.32)^2$ =	11.02 * 1 =	11.02
$(22-24.32)^2$ =	5.38 * 5 =	26.91
$(23-24.32)^2$ =	1.74 * 1 =	1.74
$(24-24.32)^2$ =	0.10 * 3 =	0.31
$(25-24.32)^2$ =	0.46 * 6 =	2.77
$(26-24.32)^2$ =	2.82 * 2 =	5.64
$(27-24.32)^2$ =	7.18 * 1 =	7.18
$(28-24.32)^2$ =	15.54 * 4 =	62.17
$(30-24.32)^2$ =	32.26 * 1 =	32.26
$(31-24.32)^2$ =	44.62 * 2 =	89.24

2. Add the total results of the last column and divide by the number of total data points.

$$\frac{\textbf{Sum total of results}}{\textbf{\# samples}} = \frac{388.30}{31} = \textbf{12.52}$$

3. Take the square root of your result in step to obtain the standard deviation for your data set.

$$\sigma = \sqrt{12.52} = 3.5$$

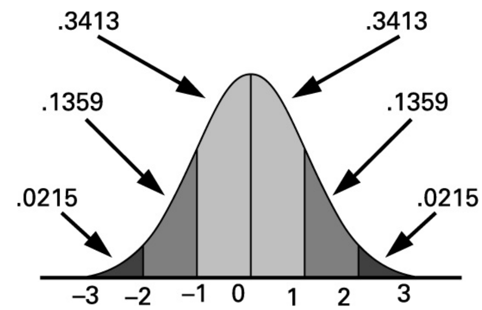
The mathematical equation to describe the operation preformed is $\sigma^2 = \frac{\sum (X - \mu)^2}{N}$ where μ is the mean, N is the number of samples, and X is a given data point.

Note: If only a portion of the data is analysed, the calculation of the standard deviation is slightly different. It becomes somewhat larger to represent the fact that there would likely be more variation if an entire sample was used in the calculation. The calculation is

$$S_x^2 = \frac{\sum (X - \mu)^2}{N - 1}$$

(For our temperature data the sample mean would be 3.6.)

A normal curve is used with this statistic to analyse a set of data. A normally distributed set of data uses the mean as a start point and then shifts in standard deviation units to the left and right of this mean. The picture to the right shows a normal curve.



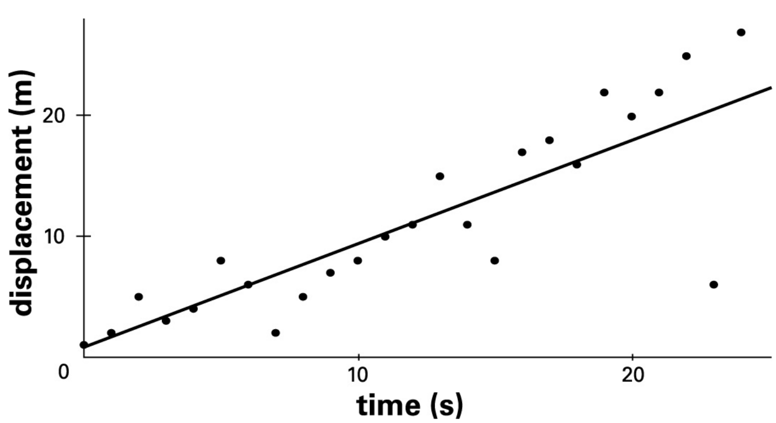
This curve shows that 34.13% of the results should be within one standard deviation left and one standard deviation right of the mean for a normally distributed set of data. With our mean of 24.32° C, 68.26% of our data should lie between 20.82° C and 27.82° C. Another interpretation from this curve is that 95.44% of the values are found below two standard deviations from the mean. For our data that would imply that 95.44% of the temperatures are between 17.32° C and 31.32° C. If the data does not fall into these ranges, it would suggest that there is something unusual about our sample, or that our sample is too small.

(The actual ranges for our data are 19/31 (61.29%) within one standard deviation and 30/31 (96.77%) within two standard deviations. Our data is basically normally distributed.)

Best Fit Analysis: Lines of Best Fit and Med-Med Graphs

One of the most common methods of data analysis is the line of best fit. When data is plotted on a (*x.y*) coordinate system, a linear pattern often arises as a way to describe the relationship between two variables in an experiment or study.

Example: The following data set represents the displacement an object has travelled from its start position over time. The *x*-axis is the time in seconds, and the *y*-axis is the displacement in metres.



time(s)	displacement (m)
0	1
1	2
2	5
3	3
4	4
5	8
6	6
7	2
8	5
9	7
10	8
11	10
12	11
13	15
14	11
15	8
16	17
17	18
18	16
19	22
20	20
21	22
22	25
23	6
24	27

The line of best fit for this data can be described by the equation $d(t) = 0.89t + 0.49$. From this we can assume that the velocity of the object is approximately 0.89 m/s.

A visual examination of the graph shows that a large number of data points stray far away from the plot line. These points or outliers can skew the results of our line of best fit and introduce data into our analysis. In order to remove the possibility of this error a median-median plot can be used.

To create a med-med plot the data must first be sorted into three groups. Those in the bottom third of *x*-values, those in the middle third of the *x*-values, and those in the top third of *x*-values. The sets are then arranged so both the *x*- and *y*-values are in ascending order. The median of these points is then used to set up the linear plot. The median of the low set and the high set are plotted on a graph, and the equation of the line connecting them is determined. The slope of this line is the slope of the med-med line. The *y*-intercept is determined using the middle third point. The entire line is shifted one third of the distance towards the line, and the line of the med-med plot is determined. This new line greatly reduces the value of outliers in a plot.

Bottom 1/3

0	1
1	2
2	5
3	3
4	4
5	8
6	6
7	2

Bottom 1/3 Sorted

0	1
1	2
2	2
3	3
4	4
5	5
6	6
7	8

Middle 1/3

8	5
9	7
10	8
11	10
12	11
13	15
14	11
15	8
16	17

Middle 1/3 Sorted

8	5
9	7
10	8
11	8
12	10
13	11
14	11
15	15
16	17

Bottom 1/3

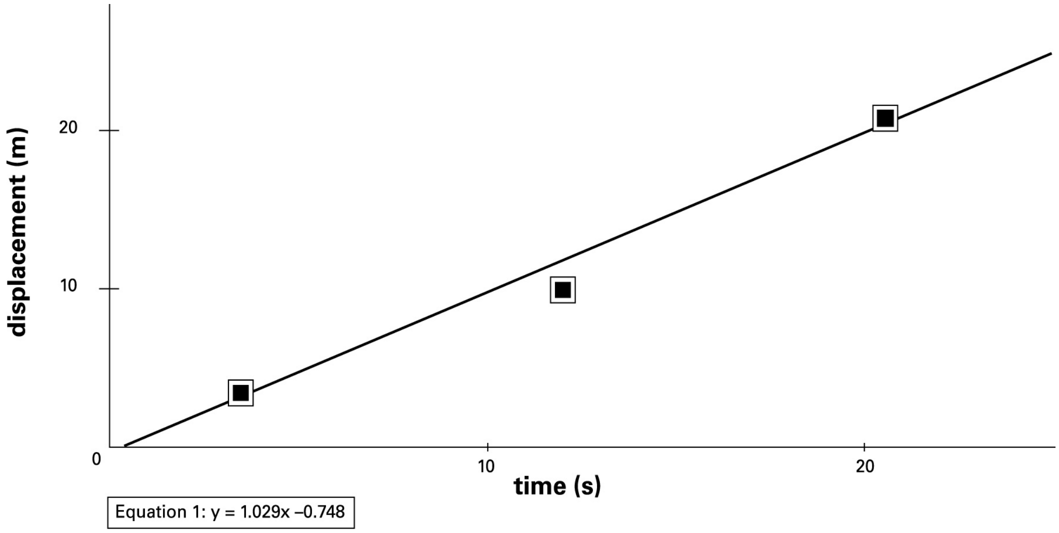
17	18
18	16
19	22
20	20
21	22
22	25
23	6
24	27

Bottom 1/3 Sorted

17	6
18	16
19	18
20	20
21	22
22	22
23	25
24	27

The median of bottom third is (3.5, 3.5), the median of the middle third is (12,10), and the median of the top third is (20.5, 21). Using the high and low points we get an equation of $d(t) = 1.029t - 0.103$. By substituting in t-12 from the middle median results in 12.245. This is subtracted from the *y*-coordinate of the middle median 10 – 12.245 = –2.245, and the result is divided by 3; $\frac{-2.245}{3} = -0.748$. This is the value of the *y*-intercept for the med-med line. Thus the equation for the med-med line is $d(t) = 1.029 - 0.748$.

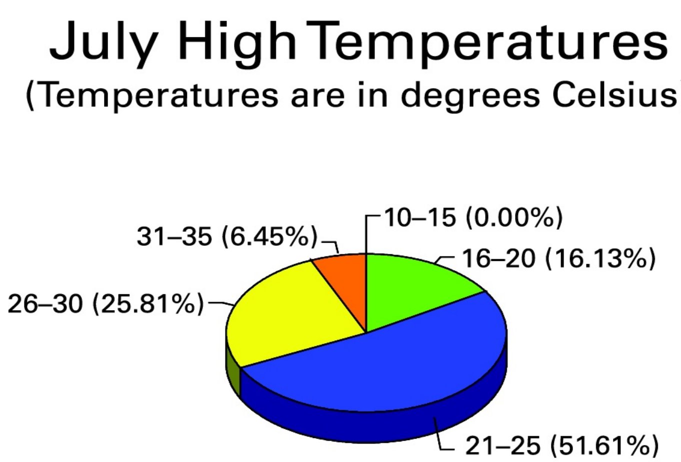
This line gives a better representation of the trend in position-time data, minimizing the effect of variations in data sets.



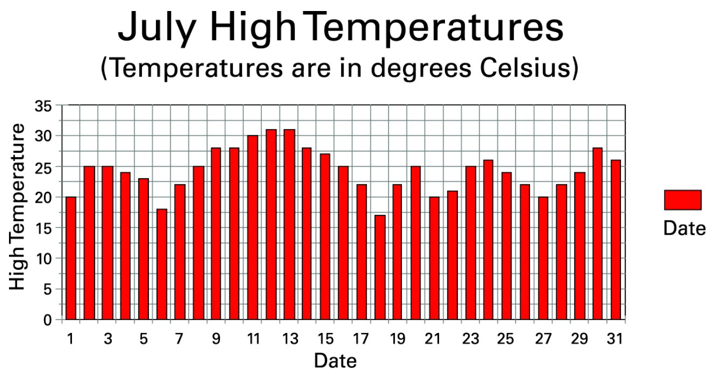
Data Displays

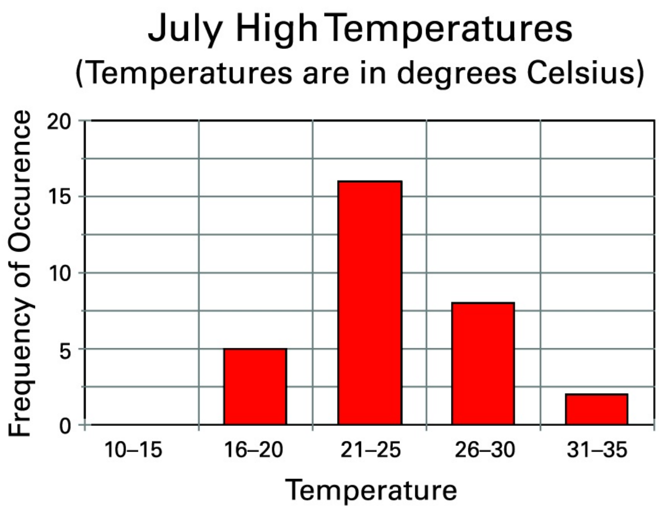
Graphical displays of data allow a study to be quickly analysed and examined for trends. Some examples of graphs that can be used are shown below.

A. **Pie charts** show the percentage distribution of data based on defined ranges.

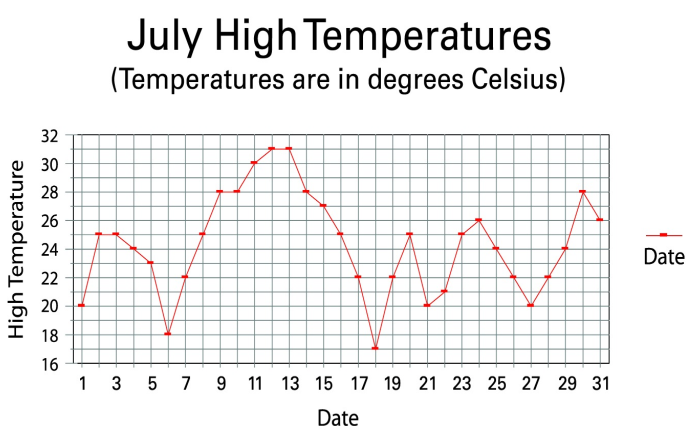


B. **Bar Graphs** show data trends in a number of used defined settings, for example, daily temperatures or specific temperature ranges.





C. **Line graphs** are similar to bar charts, which easily describe the changes in data points.



Bibliography

Print Resources

Atlantic Provinces Education Foundation. *Foundation for the Atlantic Canada Science Curriculum*. Halifax, NS: Atlantic Provinces Education Foundation, 1998. (64311)

Brennan, Richard P. *Heisenberg Probably Slept Here: The Lives, Times, and Ideas of the Great Physicists of the 20th Century*. Mississauga, ON: John Wiley & Sons, 1998.

Council of Ministers of Education, Canada. *Common Framework of Science Learning Outcomes K to 12: Pan-Canadian Protocol for Collaboration on School Curriculum* (October 1997), www.cmec.ca/science/framework/pages/english/cmec%20Eng.html.

Giancoli, Douglas C. *Physics: Principles with Applications*, 5th edition. Upper Saddle River, NJ: Prentice Hall, 1997. (ISBN: 9780136119715)

Nova Scotia Department of Education. *Atlantic Canada Science Curriculum: Physics 11 and Physics 12*. Halifax, NS: Province of Nova Scotia, 2002.

Nova Scotia Department of Education. *A Closer Look: Doing Project-based Science*. Halifax, NS: Province of Nova Scotia, [2010?].

Speyer, Edward. *Six Roads from Newton: Great Discoveries in Physics*. Mississauga, ON: John Wiley & Sons, 1994. (ISBN: 9780471159643)

Authorized Learning Resources

The following resources to support teaching and learning in science are currently available through the Nova Scotia School Book Bureau. The NSSBB number is given in parenthesis. For more details, visit the website (https://w3apps.EDnet.ns.ca/nssbb).

McGraw-Hill Ryerson Physics (22906, 22966)
The Five Biggest Ideas in Science (17123)

Websites

Institute of Physics: Careers: Schools & Colleges
www.iop.org/activity/careers/Careers_Schools_and_Colleges/page_25768.html

Institute of Physics: Careers & Beyond
www.iop.org/activity/careers/Careers_University_and_Beyond/Students/index.html

APS Careers in Physics
www.aps.org/jobs