

Physics

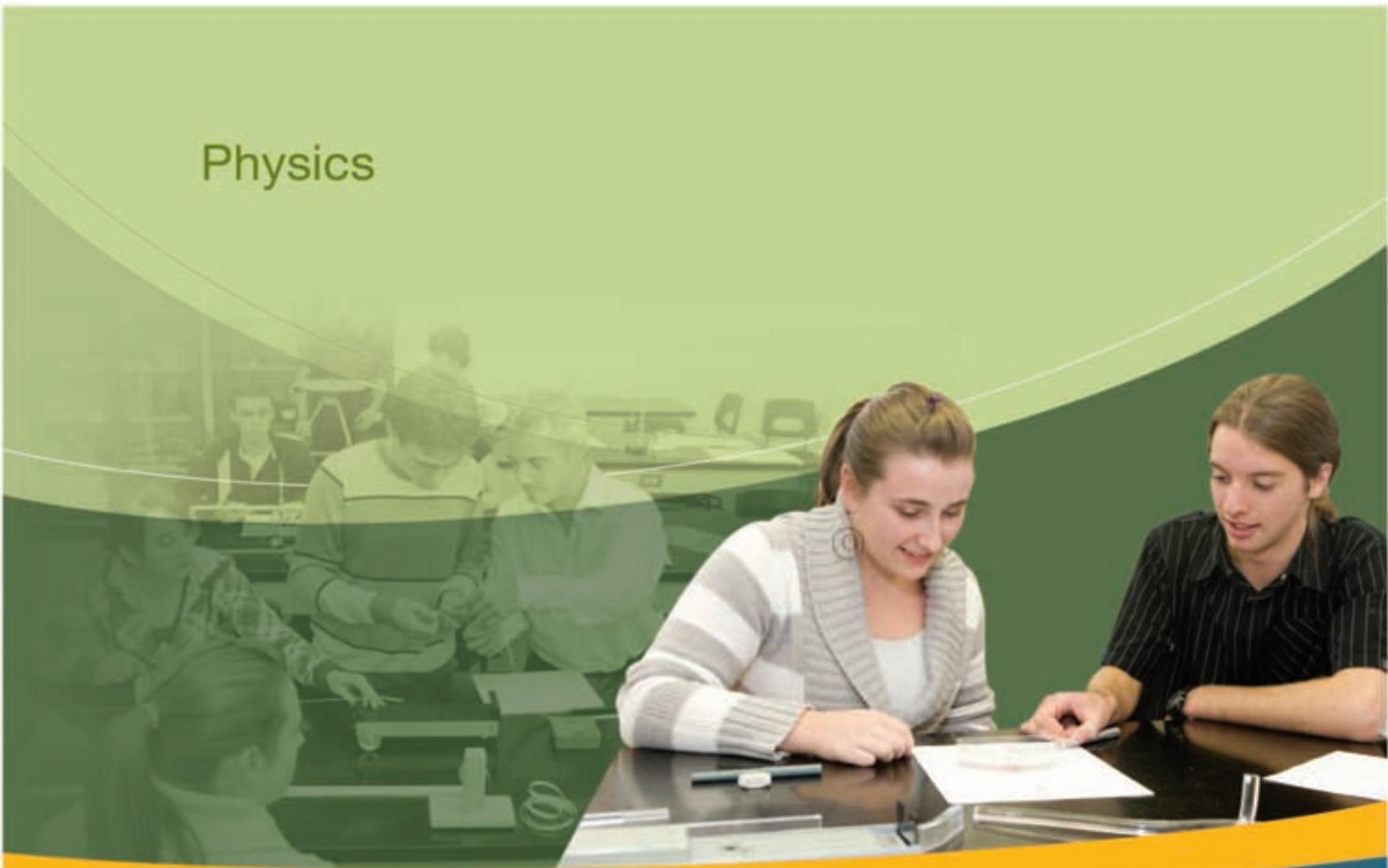


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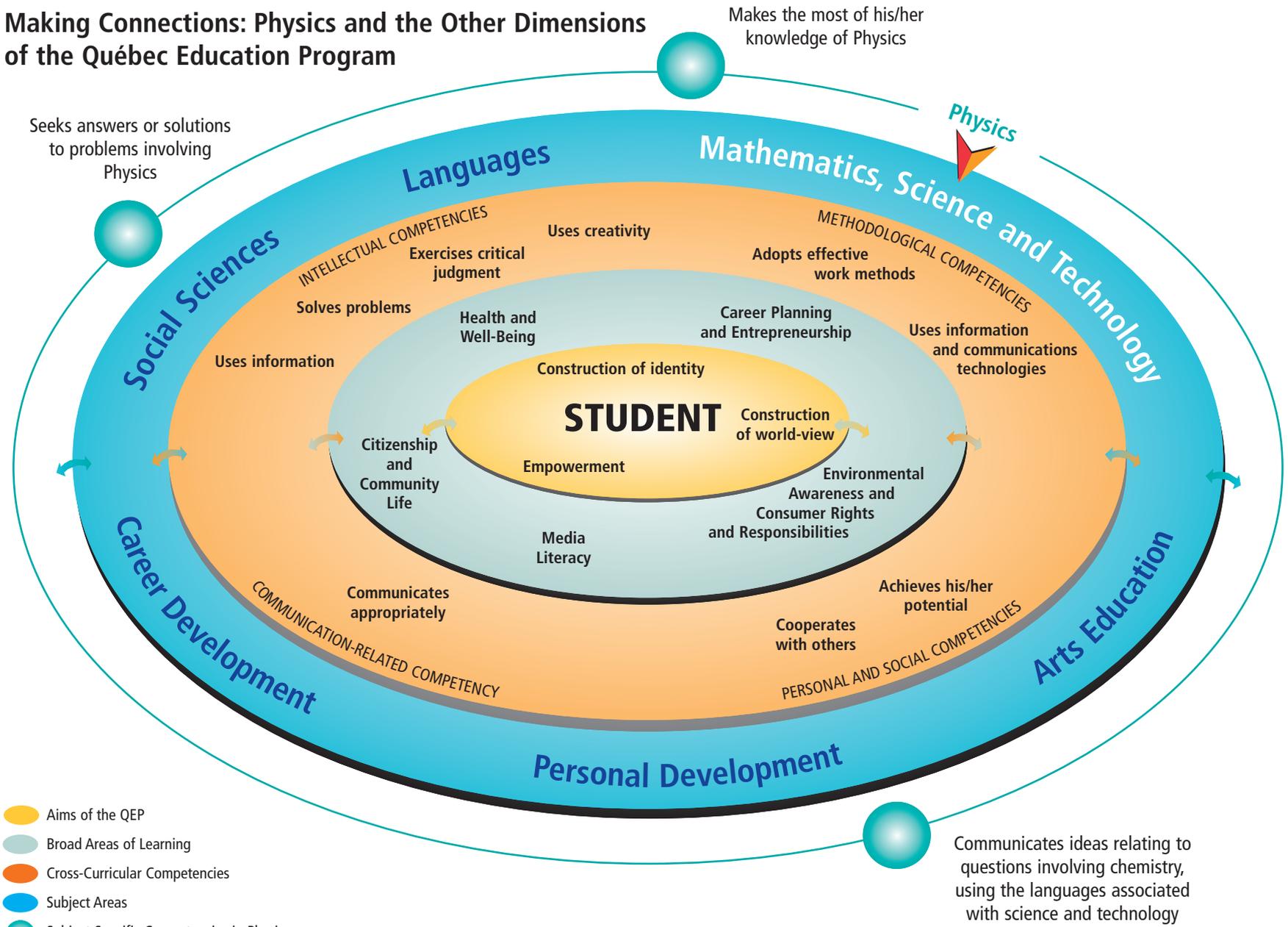
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Making Connections: Physics and the Other Dimensions of the Québec Education Program



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Communicates ideas relating to questions involving chemistry, using the languages associated with science and technology



Introduction to the Physics Program

Science is a means of analyzing the world around us. Its aim is to describe and explain certain aspects of our universe. Made up of a set of theories, knowledge, observations and methods, it is characterized by its attempt to develop simple, intelligible models to explain our complex world. These models can then be combined with existing models to arrive at increasingly complex visions. As we construct new knowledge, these theories and models are constantly being tested, modified and reorganized.

Among other things, physics deals with the fundamental components of the universe and their interactions, and with forces and their effects. It attempts to explain various phenomena by establishing the laws that govern them. It develops formal models to describe and predict changes in systems.

Physics is also of major practical importance, making contributions to chemistry and engineering for instance. The inventions and innovations associated with physics reflect its vitality and the essential role it has played

Physics deals with the fundamental components of the universe and their interactions, and with forces and their effects.

in the development of society. Be it with regard to health care, sports and recreation, energy resources, transportation or telecommunications, it makes a significant contribution to everyday life.

Faced with the rapid emergence of large amounts of complex scientific knowledge and the proliferation of its applications,¹ people must acquire knowledge specifically related to physics and develop strategies that enable them

to adapt to new constraints. This requires that they see the achievements of science in perspective and appreciate the impact, scope and limitations of this knowledge.

Scientific Literacy

As an integral part of the societies it has played a major role in shaping, science represents both an important aspect of our cultural heritage and a key factor in our development. It is important to help students gradually develop their scientific literacy, to make them aware of the role that such literacy plays in their ability to make informed decisions and to give them the opportunity to discover the pleasures of science.

Curiosity, imagination, the desire to explore and the pleasure of experimentation and discovery are just as much a part of scientific activities as the need to acquire knowledge and understand, explain and create. In this regard, the field of science is not the preserve of a small group of experts. We all have a certain degree of curiosity about the phenomena around us and a fascination with scientific invention and innovation.

The history of science is an integral part of this literacy and should be drawn upon. It puts scientific discoveries in perspective and enriches our understanding of them. Museums, research centres, engineering firms, health care facilities, local factories, businesses and other community organizations provide a wealth of resources for the development of scientific literacy.

As an integral part of the societies it has played a major role in shaping, science represents both an important aspect of our cultural heritage and a key factor in our development.

1. As presented in the Applied Science and Technology program, an “application” refers to a practical achievement, whether a technical object, a system, a product or a process.

The Program

The Physics program is an extension of the programs in Secondary Cycles One and Two. It is intended to consolidate and enrich students' scientific training and is a prerequisite for several preuniversity or technical programs at the college level. Its content focuses on one subject with compulsory concepts organized around four general concepts: kinematics, dynamics, transformation of energy and geometric optics. The content is addressed in meaningful contexts² that may require the application of knowledge related to the major areas of study in previous science and technology programs or knowledge associated with various subjects, themes and problems. In particular, special attention must be paid to strengthening the link between physics and mathematics.

The Physics program is designed to develop the following three competencies:

- Seeks answers or solutions to problems involving physics
- Makes the most of his/her knowledge of physics
- Communicates ideas relating to questions involving physics, using the languages associated with science and technology

These competencies are closely linked and related to three complementary aspects of science: the practical and methodological aspects; the theoretical, sociohistorical and environmental aspects; and the aspects relating to communication. The competencies must be developed to a high level, in particular because of the complexity of the compulsory concepts involved.

The first competency focuses on the methodology used in the sciences to solve problems. Students must become familiar with concepts and strategies using the experimental method, among other things. The students must ask questions, solve problems and find solutions through observation, modelling, measurements and experiments.

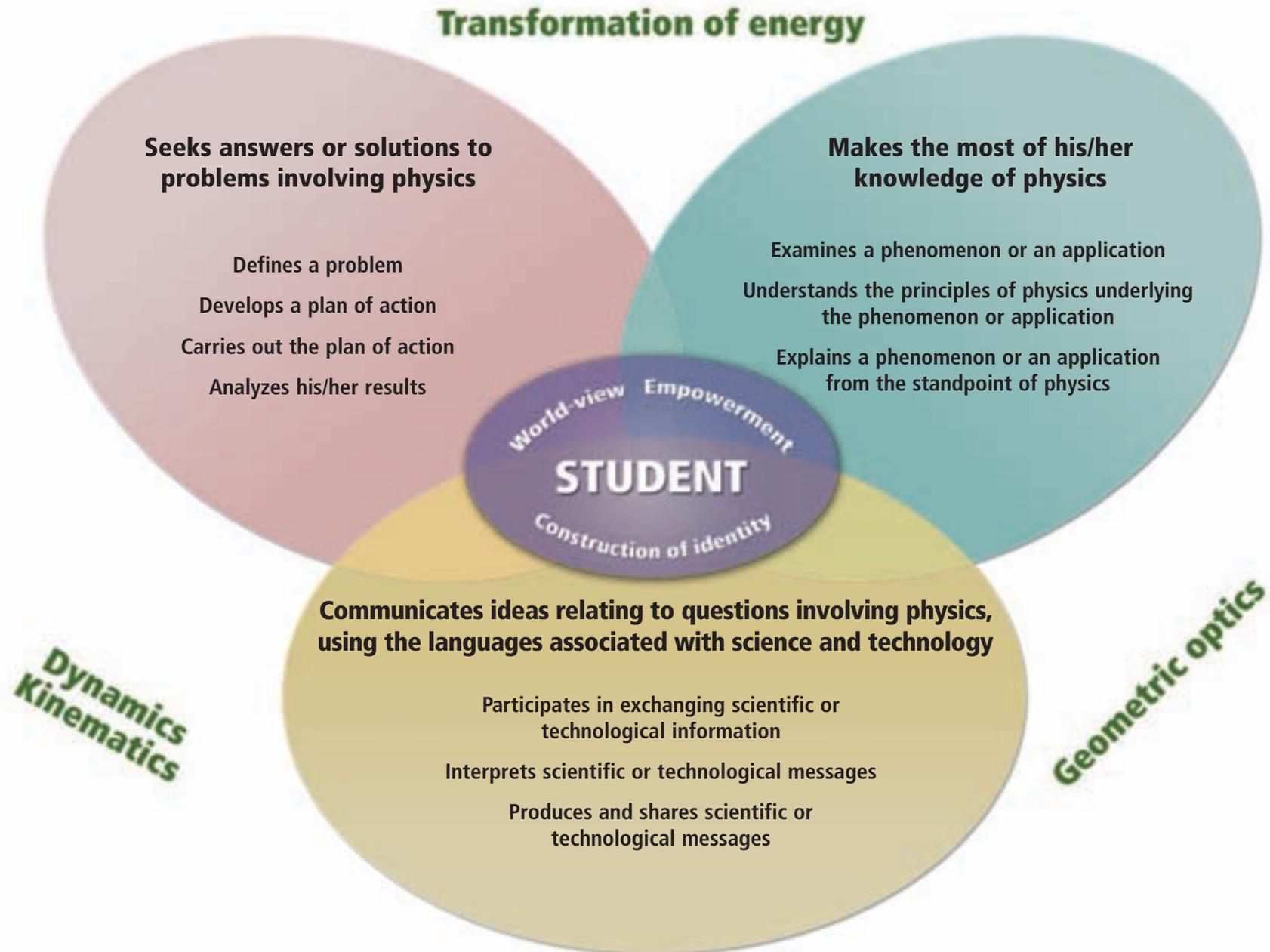
The second competency focuses on the analysis of phenomena and applications. The students must examine phenomena and applications and learn the concepts of physics that allow them to be understood and explained.

The third competency involves the different types of languages used in physics, which are essential for sharing information as well as interpreting and producing scientific and technological messages. The students are asked to participate actively in exchanges, using the languages of science and technology in accordance with established rules and conventions.

These competencies are developed together and not in isolation or sequentially. In order to master scientific methods, students need to know and be able to use the related concepts and languages. They become familiar with these methods in different contexts that give them meaning and importance.

2. With regard to each major area of study (i.e. The Material World, The Living World, etc.), Appendix A lists some of the concepts studied previously, as well as possibilities for contextualization.

CONTRIBUTION OF THE PHYSICS PROGRAM TO THE STUDENT'S EDUCATION



Making Connections: Physics and the Other Dimensions of the Québec Education Program

In a variety of ways, the Physics program is related to the other dimensions of the Québec Education Program (i.e. the broad areas of learning, the cross-curricular competencies, the Mathematics program and the other subject areas, as well as the Integrative Project).

Connections With the Broad Areas of Learning

Because of the ways in which science affects human health and well-being, the environment and the economy, there is significant overlap between the various contexts associated with the broad areas of learning and the issues and challenges raised by discoveries and inventions.

Health and Well-Being

The knowledge that students acquire in studying physics can provide answers to many questions related to how the body works as well as health, safety and comfort. In the arts, sports and various occupations, students can execute movements more efficiently, effectively and safely if they understand the forces controlled by or that act upon the human body as well as the work done by these forces. This knowledge can also be used to adapt various objects and systems (e.g. orthotic and prosthetic devices) to the specific biomechanical profile of individuals.

Environmental Awareness and Consumer Rights and Responsibilities

Scientific and technological knowledge helps young people increase their awareness of specific issues pertaining to their environment, such as the use of natural resources, human impact on the environment and waste management. Much advancement in science has led to consumer habits that have various consequences for the environment. Greater awareness of these environmental effects can lead to a change in behaviour. For example, an examination of the concepts connected with the transformation of energy can lead to a discussion of responsible resource use.

Media Literacy

Whether it be to learn, to obtain information or to communicate, students use the various media. It is important that they learn to take a more critical view of the information they find. They must become proficient in using media-related materials and communication codes and come to understand the growing impact the media have in society and in their own everyday lives. Movies, newspapers, television and various electronic media address scientific and technological topics that can be linked to the students' everyday lives in many different ways. A strong grounding in science is often useful for assessing information. These resources must be used to advantage by teachers, who can also capitalize on students' interest in various means of communication to place their learning in context and thereby increase their motivation.

Career Planning and Entrepreneurship

The variety of activities that students are asked to carry out in the Physics program can help them better understand the work of people employed in this field and apply it to their personal planning.

The program competencies, along with several of the underlying concepts, strategies, techniques, attitudes and methods, will be useful in many employment sectors including occupational therapy, aeronautics and computer animation. Teachers can help their students become aware of these sectors, and gauge their interest in and aptitude for the related professions. This awareness is especially important at the end of secondary school, when students must define their future academic and career paths.

The broad areas of learning are related to major issues of today. In its specific way of dealing with reality, each subject sheds a different light on these issues, helping students develop a broader world-view.

Citizenship and Community Life

The scientific and cultural literacy that students gradually acquire gives them a new perspective on certain social issues, which may improve the quality of their participation in the classroom, the school or society in general. Various activities, such as those relating to safe driving, are examples of situations that can help students learn about responsible citizenship.

Connections With the Cross-Curricular Competencies

The subject-specific competencies offer a solid basis for the development of the cross-curricular competencies, which, in turn, help broaden the scope of application of the subject-specific competencies.

Intellectual Competencies

Intellectual cross-curricular competencies play a crucial role in physics. The search for answers to scientific questions requires that students use information judiciously and question the reliability of their sources. It also helps them acquire new problem-solving skills and adapt them to specific situations. Developing and implementing a plan of action to solve a problem, or explaining a phenomenon or application are all ways of using creativity.

Cross-curricular competencies are not developed at a theoretical level; they are rooted in specific learning contexts, usually subject-related.

Today's society is characterized by the emergence of pseudosciences. Students must therefore learn to exercise critical judgment, especially when analyzing certain advertisements, certain scientific opinions or certain consequences of science and technology. They must try to keep media influences, social pressures and conventional wisdom in perspective in order to determine what has been validated by the scientific and technological community and what is being reported by other groups.

Methodological Competencies

The precision associated with the methods used in this program requires that students adopt effective work methods and comply with related standards and conventions.

The rapid development of information and communications technologies has played a significant role in recent advances in the world of science and technology. Using various technological tools (e.g. data-acquisition interfaces with sensors, computer-aided drafting, simulation software) in conducting experiments and solving scientific problems helps students learn to use information and communications technologies.

Personal and Social Competencies

When they take hypotheses or solutions into consideration, when they move from the abstract to the concrete or from decision to action, students are open to the range of human possibilities. They can see a greater variety of options and agree to take risks. With time, they learn to trust themselves and to learn from their mistakes, which allows them to explore new ways of achieving their potential.

To develop their knowledge of science, students must cooperate with others, since the sharing of ideas or points of view; peer or expert validation; and various collaborative research, experimental or problem-solving activities are part and parcel of the learning process.

Communication-Related Competency

Learning concepts and scientific and technological languages enable students to develop their ability to communicate appropriately. They must gradually discover the codes and conventions of these languages, become familiar with their uses and master them.

Students can further use and develop this cross-curricular competency when they join a virtual scientific community, for example by taking part in a discussion group or video conference to share information, communicate with experts on-line, present the results of their work or compare them with those of other students.

Connections With the Other Subject Areas

To ensure that students receive an integrated education, it is important to connect learning in physics to learning in other subjects. Any subject is defined, at least in part, by the way in which it perceives reality and by its particular view of the world. Other subjects can shed additional light on physics just as physics can help us gain a better understanding of other subjects.

Mathematics, Science and Technology

The field of mathematics is closely related to the science and technology programs. It provides a body of knowledge useful for the study of science. For example, when students follow a scientific method in Secondary V, they do not just measure, count, calculate averages, apply geometric concepts, visualize space and choose different types of representation, but also construct formal arguments or proofs. Mathematics is often of great use in developing or constructing models to explain the relationships between certain key variables. It is also used to solve both theoretical and experimental problems. Its rigorous vocabulary, graphs, notation and symbols also make mathematical language a tremendous asset to science.

Mathematics also requires the development of competencies focusing on reasoning, problem solving and communication, which are related to the competencies in the Physics program. Their combined use fosters the transfer of learning and is especially useful in developing a capacity for abstract thought and problem-solving strategies. Physics also helps students understand certain mathematical concepts, such as variables, proportional relationships, vectors and various functions.

Languages

Language subjects provide students with tools essential to the development of the competencies targeted by the Physics program. Whether the students are reading, writing or communicating verbally, the competencies they develop in English Language Arts are indispensable for interpreting information correctly, describing or explaining a phenomenon, or justifying a methodological decision. Moreover, the different terms used in science, which are often specific to the field, help enrich the students' vocabulary. It should also be pointed out that the ability to analyze and produce oral or written texts is closely related to the competency *Communicates ideas relating to questions involving physics, using the languages associated with science and technology*.

A certain level of competency in French is useful for participating in a virtual community or in national or international activities such as science fairs.

Reality can rarely be explained by concepts related to a single subject. Its multiple facets can only be understood by combining the different fields of knowledge.

Social Sciences

The study of scientific and technological developments can shed new light on contemporary issues, which are part of a historical context defined by specific social realities that sometimes require a knowledge of physics. Conversely, an understanding of these issues makes it possible to contextualize developments in physics and to better understand the challenges connected with the development of new ways of producing energy.

Arts Education

Physics benefits from the creativity promoted by arts education. Some of the methods used in this program are related to the creative dynamic shared by the four Arts Education programs. This is the case, for example, with problem solving, which requires creativity.

In turn, physics contributes to a better understanding of the arts. For example, knowledge in the fields of kinematics or dynamics can help students analyze dance movements or produce special effects in drama class.

Personal Development

In some cases, knowledge developed in physics class can be used to analyze questions raised in the Ethics and Religious Culture program. For example, an understanding of how energy is transformed is useful in ethical discussions about energy consumption issues.

Connections can also be made with Physical Education and Health. Knowledge about dynamics can be used to analyze a movement so that it can be better executed. The various movements involved in physical activities offer a range of examples that can be used to provide a context for some of the program content.

Integrative Project

All Secondary V students must now complete a personal project that meaningfully combines various aspects of what they have learned at school. A physics project which could, for example, be presented at a science fair, offers an opportunity for students to look in more depth at a topic that has attracted their interest during physics classes.

The Physics program can therefore easily be adapted to interdisciplinary activities. An integrated application of the different areas of learning in the Québec Education Program is recommended for a well-rounded education that gives students the tools they will need to deal with the realities of the 21st century.

Pedagogical Context

This section presents the pedagogical context that will help students develop the competencies and construct the scientific knowledge prescribed in the program. It first describes the role of the teacher, and then the role of the students.

Role of the Teacher

Teachers play a fundamental role in helping their students develop competencies. The support they provide must relate to the three aspects of every competency: the mobilization of resources in a specific context, the availability of resources and the ability to reflect on the process involved. Teachers must offer learning and evaluation situations that promote the development of the target competencies, support the students' learning progress and evaluate their level of competency development.³

Offering learning and evaluation situations that promote competency development

Student competency development involves situation-based pedagogy. Through varied and meaningful learning and evaluation situations that become more complex as they advance in their education, students will be able to make connections between what they know and what they have to learn, and to develop their competencies.

Complex, varied situations⁴

Competencies are demonstrated and developed in learning and evaluation situations that possess a certain degree of complexity. A complex situation calls for the use of at least one competency in its entirety, requires students to mobilize internal and external resources and acquire new knowledge, leads to a final product, and presents students with an open-ended problem that they have not solved before. Such situations generally involve a set of varied activities, ranging from free exploration to goal-oriented tasks or problems to be solved by overcoming obstacles. Some activities may include application or consolidation exercises.

In the activities they propose, teachers must ensure that most experiments are used to validate or invalidate a hypothesis or proposal made by the students. This will allow them to make connections between their previous knowledge and what they are currently learning, and also between theory and practice. As much as possible, teachers must have students prepare their own experiments so that they can create a model that will assist them in drafting an experimental procedure. In some cases, teachers can present an experiment as a demonstration.

Teachers must offer their students varied and meaningful learning and evaluation situations, support their learning progress and evaluate their level of competency development.

3. On this topic, see the section "A Renewal of Practices" in Chapter 1 of the *Québec Education Program, Secondary Cycle Two*, 16-22.

4. Appendix B contains examples of learning and evaluation situations, which in some cases indicate links with the educational aims of the broad areas of learning and the learning targeted in other subjects. They also involve using both subject-specific and cross-curricular competencies.

The active involvement of students is also indispensable in any problem-solving activity. The teacher must ensure that the students understand that the decisive step in solving a problem is its representation. The students must work on this representation throughout the problem-solving process. They should ultimately be able to construct a model of the problem, however rudimentary it may be, and adjust and supplement it until a solution emerges. In this way, the solution is closely linked to the representation.

It is important to note that learning and evaluation situations are more conducive to competency development when they are open-ended. Open-ended situations involve initial data that can lead to several different solutions. While sometimes complete, the initial data are generally implicit and may even be incomplete or superfluous. The students must therefore carry out research that can generate new learning.

Whatever the activity, reflection is a required step, in particular for problem-solving activities based on complex situations. Special attention must be paid to note taking, which can help students facing a challenge, since they record the steps in their reflection and their progress toward a solution, using partial results as data. Notes form an indispensable record of the problem-solving process, and can also be used to evaluate competency development.

In this program, contextualization helps students construct physics concepts, while giving them the opportunity to make connections with their previous studies.

Meaningful situations

Learning and evaluation situations must have meaning for students by attracting their interest and posing a suitable challenge, while demonstrating the usefulness of the knowledge involved.

The context for the situation may be linked to broad areas of learning, cultural references, the students' everyday lives, current events, or conceptual objects and materials associated with science and technology. A context of this kind is likely

to reactivate existing knowledge (scientific, technological or mathematical knowledge and prior experience). In this program, contextualization helps students construct physics concepts, while giving them the opportunity to make connections with their previous studies.

The activities making up the situation, whether repetitive strategies, exercises, specific tasks, experiments or problem solving, must reflect the teacher's pedagogical intention and the students' level of competency development. They must be part of a context that makes the learning meaningful. It is up to the teacher to ensure that the students always keep the context in mind, without overwhelming them with too much information.

Resources that can be used

In physics, as in all other subjects, the exercise of competencies is based on the mobilization of several kinds of internal and external resources: personal, informational, material, institutional and human. Personal resources consist of knowledge, skills, strategies, attitudes, techniques and methods. Some elements of the mathematics program content are among the conceptual tools needed to construct knowledge about physics. Their use helps students develop the capacity for abstract thought needed to design or analyze the formal models used by scientists.

Informational resources include textbooks, other documents and any other relevant source used to locate information. Material resources include instruments, tools and machines, as well as everyday objects. Institutional resources include public and parapublic organizations such as museums, research centres, engineering firms, health care facilities, local factories and businesses, and any other community organization. Students can use all these resources to broaden their scientific literacy.

Physics teachers and laboratory technicians are the most accessible human resources for students. Although their tasks are different, they make an essential contribution, especially in terms of safety. Input can also come from teachers of other subjects, members of the school staff, parents and experts in a particular field who are willing to contribute to the school learning process.

Supporting learning progress

Another aspect of the teacher's role is to support students as they develop competencies and, in the process, acquire knowledge. To do this, the teacher must guide them so that they can achieve the competency or master the method that, in his or her opinion, requires more attention (e.g. building a model, providing an initial explanation, using the concept of "variable," applying the concept of "measurement," representing results). The teacher may also decide to have students exercise the three competencies in an interrelated way, while focusing on one in particular.

It is important for the teacher to adapt the task to the competency level of the students, provide explanations as needed, answer their questions, suggest possible solutions, provide more supervision for the less independent students, and ensure compliance with laboratory and workshop safety rules. The teacher must also interact with the students and ensure that they interact with one another. To that end, he or she can ask them to provide explanations or examples, or trigger questions on their part by proposing counterexamples to stimulate discussion. Various pedagogical strategies, such as the problem-solving approach, case studies, academic controversy and projects, can help the students adopt a reflective approach, provided these strategies force them to ask questions and gain perspective on the process.

The teacher must provide flexible supervision, ensuring that the students are not overwhelmed by the quantity of information to be processed and helping them select relevant data to complete a task or solve a problem, as well as search for new data. The teacher must also insist on rigour, and monitor and validate the students' work. Interventions by the teacher must not devalue the students' own work, but focus on explaining mistakes and ensuring that all students learn from the mistakes identified.

The teacher is also an important resource for the students, particularly with respect to the regulation of learning and strategies involving the entire class. Carrying out these specific roles gives the teacher an ideal opportunity to refocus conceptual learning and point out connections between the students' new and prior learning. The teacher also plays an active part in reviewing and synthesizing learning with the whole class.

Evaluating the level of competency development

Evaluating the level of competency development is another important aspect of the teacher's work. According to the Policy on the Evaluation of Learning, evaluation has a dual function: to support learning and to recognize competencies.

Supporting learning

It is important for teachers to observe their students regularly to help them readjust their approach and mobilize their resources more effectively. For this purpose, they must propose a wide range of learning and evaluation situations, and present observation, evaluation and recording tools for each situation. When designing these situations and tools, teachers must base them on the evaluation criteria for the competency or competencies concerned so as to be able to formulate indicators reflecting observable behaviours that make it possible to evaluate the level of competency development. Teachers should also refer to the end-of-program outcomes and the scales of competency levels.

All actions taken by the teacher must be designed to help students become aware of their difficulties and solve them or to consolidate their learning. The teacher can observe the students as they work and intervene immediately as needed. The teacher can also record observations, which can then be used to sum up the strengths and weaknesses of each student, to review with the students the strategies used and learning acquired, and to adjust his or her teaching as required.

Only the students can make the necessary connections between their previous knowledge and the new concepts they must assimilate.

Lastly, since evaluation as a way to support learning is also a responsibility of each student, the teacher can promote self-evaluation, coevaluation and peer evaluation, and supply tools for this purpose.

Recognizing competencies

To certify each student's level of competency development, the teacher must have a sufficient amount of relevant information to be able to form a judgment. To ensure that the judgment is valid, the teacher must refer to the evaluation criteria and end-of-program outcomes for each of the three competencies, and use the scales of competency levels developed for this program.

Role of the Student

Although the teacher sets the pedagogical framework, it is important for the students to be fully engaged in the learning process. Only they can make the necessary connections between their previous knowledge and the new concepts they must assimilate, and they must also adapt their knowledge to the concepts to be learned, and vice versa.

Using situations that interest the students and place the main focus on independent activity, the teacher encourages the students to take action, reason, discuss and apply their critical judgment. This requires them to take initiative, show creativity, work independently and demonstrate intellectual rigour. To do this, they must construct and use many different internal resources (knowledge and techniques, skills, methods, strategies and attitudes). If necessary, they look for a variety of information, select material resources that can help them in their learning or consult with human resources in their immediate environment. In some cases, they should look outside their family and school environment. The local community, businesses, experts and museums can all open their eyes to the outside world and give them the opportunity to consider different points of view.

Only the students can make the necessary connections between their previous knowledge and the new concepts they must assimilate.

It is important for students to use appropriate techniques when handling equipment and substances. If they use verification or control instruments, they must take into account possible errors in their measurements, whether caused by the instrument, the user or the environment. They must record their measurements using an appropriate number of significant figures and analyze their results based on a certain margin of error. At all times, they must comply with safety standards and handle equipment and substances with care. When in doubt, they must ask the teacher or laboratory technician to ensure that they are working safely and using the equipment and substances correctly.

COMPETENCY 1 Seeks answers or solutions to problems involving physics

Focus of the Competency

Like other science subjects, physics is characterized by a rigorous approach to problem solving. The problems always involve initial information, a goal to be reached and specifications describing the nature, meaning and scope of the problem. Seeking answers or solutions to physics problems involves using different types of reasoning and methodological procedures associated with physics, which make use of strategies for exploring or analyzing and require creativity, a methodological approach and perseverance. Learning how to use these methods appropriately helps students gain a better understanding of the nature of scientific activity. This competency is therefore based on the assumption that students must be offered learning and evaluation situations that go beyond the application of known formulas.

The basic and optional science and technology programs for the first two years of Secondary Cycle Two focus on scientific or technological methods. The students gradually learn to apply several methods at once in looking for an answer or a solution to a given problem. Compared with previous years, more emphasis is placed on the quantitative aspects of problems and on mathematical formalism, in addition to qualitative considerations.

In Secondary V, science is a key focus and only scientific methods are taught. Formal logic and mathematics become increasingly important. The problems are seldom simple and raise a number of questions that can be grouped into subproblems, each referring to scientific principles and methods.

Finding answers or solutions to physics problems involves a process that is dynamic and nonlinear.

The first step in solving a problem is to determine a way of representing it based on meaningful indicators and relevant elements. At first, this representation can be rough and may require a number of adjustments throughout the process. New learning, the use of prior knowledge and information that has not yet been taken into account, discussions with peers or the teacher, unexpected experimental results as well as the reorganization of information and knowledge often lead to more refined reformulations that come closer to achieving the goal in question. The initial representation of a problem may therefore be modified over the course of the process. Sometimes, however, the initial representation needs little or no modification, if it is based on a solid foundation of knowledge. The representation of the problem is used to explore various problem-solving scenarios in order to select the best option. This is followed by planning that takes into account material limitations and constraints and the availability of resources.

The students then follow the steps in the plan of action, taking care to record all observations that might prove useful. The correct margin of error is taken into account for all measurements. New data can require a reformulation of the representation, adaptation of the plan of action or a search for a more appropriate solution.

Analysis involves the organization, classification, prioritization, comparison and interpretation of results obtained during the problem-solving process. It consists in identifying patterns and the significant relationships that characterize them, relationships among the results themselves, and relationships between the results and the initial data or between the results and the scientific concepts. This comparison makes it possible to formalize the problem and to validate or invalidate hypotheses and draw conclusions.

When analyzing the results, it is important to take uncertainty⁵ in measurements into account. By interpreting the error involved,⁶ students can assess the accuracy of their result. If necessary, they can attempt to identify the probable sources of error.

In order to ensure better use of methods and strategies, students should systematically review what they have done throughout the problem-solving process. This metacognitive task should also apply to the conceptual and technical resources used and their adaptation to the requirements of the different contexts. However systematic it may be, this problem-solving process entails research and may involve trial and error. To apply it, the students must be aware of their actions and capable of reflecting on them, and ask questions for the purpose of validating the work in progress so that necessary adjustments can be made in accordance with the stated goals or the selected options. Since their results may raise new problems, achievements are always considered temporary and are a part of a continuous process of acquiring and expanding their knowledge.

Finding answers or solutions to physics problems involves a process that is dynamic and nonlinear. This makes it necessary to move from one phase of

the problem-solving process to another and to apply the appropriate methods, strategies, techniques, principles and concepts. If these resources are to be used in combination, they must be adapted to the situation and its context.

This competency is inextricably linked to the other two and cannot be developed independently. The acquisition and use of specific knowledge is part and parcel of the process of finding solutions to physics problems. The laws, principles and concepts of physics are used to define a problem and formulate it in terms that approach an answer or solution. This competency cannot be developed without the mastery of communication strategies, since to solve physics problems the students must exchange information, and interpret, produce and share messages. The peer validation process is essential, as is the understanding and use of the language shared by members of the scientific community.

5. Uncertainty (absolute or relative) is the region on both sides of a measured value of a physical quantity where the true value is expected.

6. Error is the difference between the observed values and the generally accepted value.

Key Features of Competency 1

Defines a problem

Considers the context of the situation • Represents the problem • Identifies the initial data • Determines the elements that seem relevant and the relationships between them • Reformulates the problem in terms of physics concepts • Formulates questions, explanations or hypotheses

Develops a plan of action

Explores some of the initial explanations or solutions • Chooses an explanation or solution • Identifies the necessary resources • Plans the steps involved in its implementation

Seeks answers or solutions to problems involving physics

Carries out the plan of action

Follows the steps in his/her plan • Uses the appropriate resources • Carries out the required tests and tasks • Gathers potentially useful data or observations • If necessary, adjusts the plan of action or its implementation • Carries the plan of action through

Analyzes his/her results

Looks for significant patterns or relationships, if applicable • Makes connections between his/her results and physics concepts • Judges the appropriateness of the answer or solution found • Reviews the approach used • Suggests improvements if necessary • Draws conclusions

Evaluation Criteria

- Appropriate representation of the problem
- Development of a suitable plan of action
- Appropriate implementation of the plan of action
- Development of relevant conclusions, explanations or solutions

To evaluate the development of this competency, teachers must record a sufficient amount of relevant information about the student's work and use it to make a judgment by referring to the scales of competency levels for science and technology established by the Ministère de l'Éducation, du Loisir et du Sport (MELS).

End-of-Program Outcomes

By the end of this program, students are able to apply a process for solving practical problems involving physics. They attempt to understand the problem to be solved using the initial data provided for the situation and make connections among the given items of data. They define the goal to be achieved as well as the conditions involved in solving the problem. They reformulate the problem using physics concepts. They formulate questions, explanations or realistic hypotheses that they can justify.

The students propose a way to solve the problem. They develop their plan of action by selecting methods in order to achieve their goal. They carefully control important variables and select the relevant conceptual tools, equipment and materials.

They apply their plan of action in a safe manner and make any necessary adjustments. They collect data by correctly using the selected materials and equipment. They take the precision of the tools and equipment into account.

They analyze the data collected and formulate relevant conclusions or explanations. When presenting their results, they ensure that they use significant figures correctly, taking possible uncertainty into account. If necessary, they consider the accuracy of the result based on the discrepancy observed between their result and a generally accepted value.

If necessary, they propose new hypotheses, improvements to their solution, or new solutions. They are able to explain the steps in their approach and the way in which resources are used. If necessary, they use information and communications technologies.

Throughout the problem-solving process, the students demonstrate rigour and use appropriate qualitative explanations and mathematical formalism to support their reasoning.

COMPETENCY 2 Makes the most of his/her knowledge of physics

Focus of the Competency

In Cycle One, students learned to apply their scientific and technological knowledge by attempting to identify the consequences of science and technology and to understand natural phenomena and the inner workings of certain technical objects. In the first two years of Cycle Two, they apply what they have learned to the study of certain issues (in the Science and Technology, Environmental Science and Technology, and Science and the Environment programs) or technological applications (in the Applied Science and Technology program). In Secondary V, scientific knowledge is applied to an analysis of phenomena or applications.

In this program, the students are asked to examine, understand and explain phenomena or applications by applying the concepts of physics. It is important to specify that, in the case of an application, they do not examine technological aspects or concepts, but rather the scientific principles on which it operates. A brief technological analysis may be relevant, however, provided it highlights and clarifies the scientific principles of the application.

To develop this competency, students must first put the phenomenon or application in context by taking into account its key aspects (e.g. social, historical, environmental, economic, political, ethical or technological). This will give students the opportunity to reactivate previously acquired scientific or technological concepts. To construct an initial representation of the phenomenon or application they are examining, they must look for useful information and determine the elements that seem most relevant as well as the connections that can be made among them.

This competency requires the students to examine, understand and explain phenomena or applications by applying the concepts of physics.

From the standpoint of physics, understanding a phenomenon or application involves recognizing the principles of physics on which it is based. This means formulating a qualitative and often quantitative description of the principles at play, which will usually lead to the exploration and development of various underlying concepts, laws and models. This work should not be limited to the mastery of mathematical formalism or the execution of a fixed recipe,

since it is important for the students to first identify and then master the fundamental concepts needed to understand the principles used to explain phenomena and applications from a scientific point of view. The empirical and observation methods, analysis, and modelling are other resources that can be used to understand the principles of physics. Since the same principle may be involved in several different phenomena or applications, the students may be required in some situations to adapt their explanation to a new context.

In order to make better use of the methods and strategies involved, students should systematically review what they have done throughout the process of explaining the phenomenon or application examined. This metacognitive task should also apply to the conceptual and technical resources used and their adaptation to the requirements of the different contexts.

This competency encompasses the communication skills needed to produce, interpret and share scientific messages and to use scientific and technological languages.

Key Features of Competency 2

Examines a phenomenon or an application

Considers the elements of the context • Identifies the initial data • Determines the elements that seem relevant and the relationships between them • Creates a representation of the phenomenon or application

Understands the principles of physics underlying the phenomenon or application

Recognizes the principles of physics • Describes them qualitatively or quantitatively • Makes connections between the principles using concepts, laws or models

Makes the most of his/her knowledge of physics

Explains a phenomenon or an application from the standpoint of physics

Associates the principles described with the phenomenon or application • Develops an explanation • Questions the method used • Adapts the proposed explanation to other contexts, if necessary

Evaluation Criteria

- Formulation of appropriate questions
- Appropriate use of the concepts, laws and models of physics
- Relevant explanations
- Suitable justification of explanations

To evaluate the development of this competency, teachers must record a sufficient amount of relevant information about the student's work and use it to make a judgment by referring to the scales of competency levels for science and technology established by MELS.

End-of-Program Outcomes

By the end of this program, students can examine common applications or phenomena in context. They are able to understand and explain them using the principles of physics as well as appropriate methods, techniques and strategies.

When students analyze a situation from the standpoint of physics, they identify the phenomenon and its scientific components, constructing an initial representation that takes the relevant initial data into account.

They provide a preliminary explanation that they then develop using scientific concepts, laws and models. In the case of an application, they can handle it and take it apart as needed to understand the main subsets and the interactions of its components so that they can then associate its operation with the underlying scientific concepts or principles.

The students offer a scientific explanation for a phenomenon or an application. They justify it, using mathematical formalism among other things. When presenting their results, they ensure that they use significant figures correctly, taking possible uncertainty into account. They are able to explain their approach and the way in which resources are used. They are also able to apply their explanation to other phenomena or applications involving the same principles of physics.

COMPETENCY 3 Communicates ideas relating to questions involving physics, using the languages associated with science and technology

Focus of the Competency

Communication plays an essential role in the construction of scientific and technological knowledge. To the extent that such knowledge is developed and instituted socially, a set of common representations is required so that people can exchange ideas and negotiate points of view. This calls for a standardized language, i.e. a code that defines linguistic and graphical signs in accordance with the way they are used in the scientific and technological community. The dissemination of knowledge is also governed by certain rules. For example, research results must be validated by means of a peer review process before they are made public. Information can be communicated in different ways depending on whether it is meant for an audience of experts or nonexperts.

In this program, students are asked to use appropriate language to communicate ideas related to questions involving physics. They must know how to use the standards and conventions of science and technology in order to participate in exchanges on scientific or technological issues, or to interpret or produce scientific or technological information. They must also learn to respect the intellectual property rights of the people whose ideas and results they borrow. Although interpretation is particularly important, participation in exchanges and the production of messages also play an important role.

This competency is developed in situations in which students participate in the exchange of scientific or technological information, whether they are sharing the results of their work with peers, consulting experts to find answers to certain questions, or participating in activities such as analyzing or designing objects, systems or products, presenting a project or drafting a scientific information sheet. Particularly useful in learning to refine their representations or validate a point of view by comparing it with others, these situations must also help students develop an open-minded and receptive attitude toward the diversity of knowledge, points of view and approaches. The fact that the

This competency is developed in situations in which students participate in exchanges of information, and in the interpretation and production of scientific or technological messages.

everyday meaning of a term is sometimes different from its meaning in scientific or technological language deserves special attention. Similarly, the meaning of concepts can differ depending on the subject area in which they are used. It is therefore essential to take into account the context of the communication situation in order to determine the issues under debate and to adapt one's discourse accordingly.

Interpretation, another important feature of the competency, is involved in reading scientific or technical articles, listening to oral presentations, understanding lab reports and using specifications, technical manuals and plans.

All of these activities require that the students understand the precise meaning of words, definitions, statements, graphs, diagrams and detail drawings. They must also make explicit connections between concepts and their various graphic or symbolic representations. When consulting documents or listening to presentations, students must verify the reliability of these sources and select the information that seems appropriate to them.

In physics, producing scientific or technological messages is also an important aspect of this competency, since the situations may require that students develop a research procedure, write a lab report, prepare a technical manual, summarize an article, make a detail drawing of a part or give a presentation. The target audience must be taken into account in order to determine the context of the message, that is, the appropriate level of complexity, structure and means of presentation. The proper use of concepts, formalisms, symbols, graphs, diagrams and drawings also adds to the clarity, coherence and precision of the message. Information and communications technologies can be exceptionally useful and enriching in this type of communication.

In order to better combine production and interpretation strategies, students should review what they have done throughout their participation in the

exchange. This metacognitive task should also apply to the conceptual and technical resources associated with communication, and their use and adaptation to the requirements of the different contexts.

This competency cannot be developed in isolation from the other two competencies in the program, as it contributes to their development. The first competency, which focuses on problem solving as it relates to physics, involves following certain standards and conventions, whether in developing a research procedure or production scenario, or in explaining laws and principles or presenting the results of an experiment. Tables, symbols, graphs, diagrams, detail and general drawings, scale models, mathematical equations and models can all be used to present information, but it is important to use them in accordance with the rules specific to the fields of science, technology and mathematics.

The scientific concepts related to physics, which are the focus of the second competency, cannot be learned or used in isolation from a language and a certain type of discourse. For example, scientific laws are a way of modelling phenomena and are usually expressed through definitions or mathematical formalism. Understanding these laws means being able to associate them with the phenomena they represent or the applications that give them concrete expression.

Key Features of Competency 3

Participates in exchanging scientific or technological information

Is open to other points of view • Validates his/her point of view, explanation or solution by comparing it with others • Integrates appropriate scientific and technological terms into his/her oral and written vocabulary

Interprets scientific or technological messages

Makes sure the sources are reliable • Identifies relevant information • Understands the precise meaning of words, definitions and statements • Makes connections between concepts and their various graphic or symbolic representations • Selects the significant elements

Communicates ideas relating to questions involving physics, using the languages associated with science and technology

Produces and shares scientific or technological messages

Takes the target audience and context into account • Structures his/her message • Uses the appropriate types of language in accordance with established standards and conventions • Uses the appropriate forms of presentation • Demonstrates rigour and coherence

Evaluation Criteria

- Accurate interpretation of scientific or technological messages
- Appropriate production or sharing of scientific or technological messages
- Use of appropriate scientific and technological terminology, rules and conventions

To evaluate the development of this competency, teachers must record a sufficient amount of relevant information about the student's work and use it to make a judgment by referring to the scales of competency levels for science and technology established by MELS.

End-of-Program Outcomes

By the end of this program, students can interpret and produce physics-related scientific or technological messages in oral, written or visual form.

When interpreting messages, they use the languages associated with physics. They correctly use scientific, technological, mathematical, symbolic and everyday language depending on the situation. They take the reliability of their sources into account.

If necessary, they define the words, concepts and expressions used by referring to reliable sources. They review all the information consulted and then identify and use the elements they deem relevant and necessary for an accurate interpretation of the message.

They produce clear, well-structured and well-worded messages. They follow conventions, while using the appropriate means of presentation. They select and use necessary tools, such as information and communications technologies, which help them deliver their message effectively. At all times, they adapt their messages to their target audience. Using everyday language, they are able to explain the messages they have produced or interpreted.

When necessary, the students compare their ideas with those of others. They defend their ideas, but adjust them when other people's arguments can help fine-tune their thinking. They always respect intellectual property rights in producing their messages.

Program Content: Constructing and Using Resources

Like the other Science and Technology programs, the Physics program is aimed at consolidating and enriching students' scientific and technological literacy. It is also designed to educate students about the impact of science on individuals, society and the environment, and to prepare some students for a scientific or technological career.

The resources to be developed in this program complement those developed in previous science and technology programs to allow students to use concepts in a more specialized way in a wider range of contexts connected with the material, living and technological worlds as well as Earth and space. The contextualization suggestions in Appendix A provide valuable opportunities for the development of the target competencies and resources.

The resources are presented in two parts. The first part addresses the compulsory concepts, and the second part focuses on the methods, strategies and attitudes that students must acquire, along with compulsory techniques. In essence, the methods correspond to the problem-solving approaches normally used in the sciences. The strategies are implemented to ensure better use of the methods. The attitudes, whether linked to knowledge or skills, help the students develop a sense of commitment to and responsibility for their work. Lastly, the techniques involve methodical procedures often used in the sciences, and play a fundamental role in competency development.

It is important to note that, in this program, the targeted level of concept and competency development requires students to use various mathematical concepts related to algebra, trigonometry, geometry and analytic geometry, including vectors. These concepts are covered in the mathematics programs from preceding years, or in each mathematics option in the second and third years of Secondary Cycle Two, except for vectors, which are not examined in the Cultural, Social and Technical option.

Compulsory Concepts⁷

The compulsory concepts are organized around general concepts related to kinematics, dynamics, transformation of energy and geometric optics. They are presented in a two-column table. The first column lists the general concepts and orientations, which develop, set and specify the conceptual foundations, while giving teachers a certain amount of latitude. Occasionally, additional notes provide information about the scope of the concepts under study. The second column lists the compulsory concepts, but teachers should in no way feel bound by this list. The learning and evaluation situations should in fact be designed to go beyond these minimum requirements.

A table of cultural references follows. These references can enrich learning and evaluation situations and contribute to the development of integrative educational activities that reflect the students' social, historical, cultural and everyday reality. Connections can often be made to the broad areas of learning and to the other subject areas.

7. Appendix C contains a synoptic table showing all compulsory concepts associated with The Material World and covered from Secondary I to V.

Orientation	Compulsory Concepts
<p>Kinematics</p> <p>Everywhere around us and inside us, things are vibrating and moving around in relation to each other. There is no absolute reference system to describe motion; motion is considered in relation to a chosen reference system. The motion of objects generally results from a combination of various types of movement. Uniform rectilinear motion and uniformly accelerated rectilinear motion (like a body on an inclined plane or in a free fall) are studied in depth, using a range of concepts (position, displacement, distance, time, velocity, change in velocity, acceleration) that must be differentiated and compared.</p> <p>Data-based equations and graphs (position, velocity and acceleration as a function of time) are an essential form of representation. Equations and graphs describe the relationships among variables and highlight trends in the changes observed. Connections can be made between equations of motion and their graphical representation. In addition, by interpreting a single graph, the other two graphs can be deduced.</p> <p>Changes in position, velocity and acceleration are regarded as vector quantities, and students must master operations involving them.</p> <p>Complex motion, such as that of projectiles, is decomposed into simpler motions.</p>	<ul style="list-style-type: none"> – Reference systems – Uniform rectilinear motion <ul style="list-style-type: none"> • Relationship among position with respect to the point of origin, velocity and time • Displacement and distance – Uniformly accelerated rectilinear motion <ul style="list-style-type: none"> • Relationship among acceleration, change in velocity and time • Relationship among acceleration, distance and time • Average velocity and instantaneous velocity • Motion of a body on an inclined plane • Free fall – Motion of projectiles
<p>Dynamics</p> <p>Dynamics studies the causes of changes in motion. The program looks only at the forces acting on bodies moving in a straight line. Newton's laws describe the effect of forces acting on a body (friction, gravity, centripetal force). Mechanical systems, whether in equilibrium or not, are studied by drawing a free-body diagram, which is a vectorial representation of the forces acting on a system. Various methods can be used to determine the characteristics of the vectors representing the resultant and balancing forces for the system of forces in question.</p> <p>For a body in free fall, special attention is paid to gravitational force, which leads to the study of the concept of gravitational acceleration.</p>	<ul style="list-style-type: none"> – Newton's laws – Free-body diagram – Equilibrium and resultant of several forces – Force of friction – Gravitational force – Centripetal force – Gravitational acceleration
<p>Transformation of energy</p> <p>The concepts previously seen in connection with the transformation of mechanical energy were examined in an environmental context. In this program, the same concepts can be applied to other contexts.</p> <p>The transformation of energy is mainly studied from the standpoint of kinetic and potential energy, for example by examining an application that includes a spring, a simple machine or a complex system. The concepts of work, power, energy, elasticity and heat are examined from this standpoint as well.</p> <p>Note: Hooke's law is studied only in connection with helical springs.</p>	<ul style="list-style-type: none"> – Relationship among power, work and time – Mechanical energy – Hooke's law

Orientation	Compulsory Concepts
<p>Geometric optics</p> <p>Concepts pertaining to the deviation of light were studied at the beginning of Secondary Cycle Two. The focus in this program is on geometric optics, which deals with phenomena related to the trajectory of light and more specifically with the ways in which light is deviated by obstacles such as water surfaces, mirrors, dew drops and lenses. Geometric optics is based on the concept of light rays, a theoretical construct indicating the direction in which light travels. These rays are considered to be straight when they travel through transparent, homogeneous media.</p> <p>Snell's laws are used to make qualitative and quantitative predictions regarding the reflection and refraction of light rays (incident beam) that strike a surface separating two different media. In some cases, the incident beam may be totally reflected, meaning that no light is refracted. In addition, one of these laws can be used to calculate the refractive index of each transparent medium through which light travels.</p> <p>Reflection and refraction are associated with various phenomena and are the basis for a number of common applications. Thin lenses (converging, diverging) and mirrors (plane, spherical) are used to observe microscopic or distant objects or to correct certain visual defects. Students will learn to distinguish between real and virtual images and study the relationship used to calculate and predict the position and size of an image as a function of the position and size of an object.</p> <p>Note: Magnifying power will not be studied.</p>	<ul style="list-style-type: none"> – Snell's laws <ul style="list-style-type: none"> • Reflection <ul style="list-style-type: none"> - Incident and reflected rays - Angle of incidence and reflection • Refraction <ul style="list-style-type: none"> - Incident and refracted rays - Angle of incidence and refraction - Index of refraction – Images <ul style="list-style-type: none"> • Type of image (real, virtual) • Image characteristics (magnification, position)

Possible Cultural References		
History	Community resources	Events
Archimedes Sofia Brahe René Descartes Galileo Galilei Robert Hooke James Joule Isaac Newton Willebrord Snellius James Watt	Association francophone pour le savoir (ACFAS) Canadian Association of Physicists (CAP) Canadian Space Agency (CSA) Conseil de développement du loisir scientifique (CDLS) National Research Council Canada (NRC) Ordre des ingénieurs du Québec (OIQ)	Engineering challenges Nobel Prize for physics Science fairs

Methods, Strategies, Attitudes and Techniques

This section addresses the methods, strategies, attitudes and techniques recommended in the program. While they are different from the concepts, these elements are just as important in the development of competencies. They are designed to consolidate the elements covered in the first two years of Cycle Two.

Methods

Methods require special attention. They should not be applied in isolation, but in learning and evaluation situations in which several of them are combined. The ability to apply these methods in combination is an indicator of proficiency.

Five methods are presented here: modelling, observation, analysis, and the experimental and empirical methods.

Modelling

Modelling consists in constructing a representation of an abstract situation, one that is difficult to observe or impossible to see. This representation can be a text, a drawing, a mathematical formula, a chemical equation, a software program or a scale model. Over time, the model becomes more refined and complex. It may be valid only for a certain amount of time and in a specific context and, in many cases, it must be modified or rejected. It is also important to consider the context in which it was created. A model must help people understand a given reality, explain certain properties of that reality and predict new observable phenomena.

Observation method

The observation method is an active process intended to help the observer interpret facts on the basis of his or her predetermined criteria and generally accepted criteria within a given field. In light of the information collected, the students gain a new understanding of the facts, which is inextricably linked to the context in which the observations were made. In his or her interpretation and organization of information, the observer reinterprets the physical world on the basis of his or her assumptions and the conceptual schemes that are an integral part of what he or she brings to the observation process. All observations involve a theoretical model established by the observer.

Analysis

The elements that determine or make up a phenomenon, an object or a system, as well as the interactions between these elements, can be identified through analysis. Analysis also leads to the identification of structural and functional components, which can in turn be analyzed, and to the determination of their hierarchical or interdependent connections. In some cases, this method involves using a broader understanding of a system to determine the function of its parts and the relationships between them, thereby making it possible to highlight the dynamics of a complex system and examine its behaviour over time. This aspect of the analytical method is particularly useful in studying phenomena and applications.

Experimental method

The experimental method begins with the formulation of preliminary explanations. Then students can begin looking for an answer and defining the framework of the experiment. It then becomes necessary to develop an experimental procedure in order to identify a certain number of variables to be manipulated. The aim of the procedure is to identify and compare observable or quantifiable elements and check them against the initial hypotheses. Moving back and forth between the different stages of the experimental method raises new questions and allows students to formulate new hypotheses, adjust the experimental procedure and take the limitations of the experiment into account.

Empirical method

The empirical method involves field research without any manipulation of variables. Its spontaneity does not detract from the methodology involved (for example, a sample survey is an empirical approach that leaves nothing to chance). Often based on intuitive models, this method sometimes provides a way of exploring and representing the elements of a problem. Often, it can lead to a number of preliminary ideas, hypotheses and theories, as well as new techniques and possible avenues for other research projects.

Strategies

Some strategies used in science can help students develop the program's three competencies.

Exploration strategies	Analytical strategies
<ul style="list-style-type: none"> – Collecting as much scientific and contextual information as possible to define a problem or predict patterns – Referring to similar problems that have already been solved – Generalizing on the basis of several structurally similar cases – Anticipating the results of a method – Developing various scenarios – Exploring various possible solutions – Considering various points of view on scientific issues 	<ul style="list-style-type: none"> – Identifying the constraints and important elements related to the problem-solving situation – Dividing a complex problem into simpler subproblems – Using different types of reasoning (e.g. inductive and deductive reasoning, comparison, classification, prioritization) in order to process information – Reasoning by analogy in order to process information and adapt his/her scientific knowledge – Selecting relevant criteria to help him/her determine where he/she stands on a scientific issue.

Attitudes

The adoption of a variety of attitudes makes it easier for students to invest in the methods used and to develop a sense of responsibility for their own actions and with respect to society in general. Attitudes are an important factor in the development of the competencies.

Intellectual attitudes	Behavioural attitudes
<ul style="list-style-type: none">– Curiosity– Sense of initiative– An inclination to take intellectual risks– Interest in comparing different ideas– Receptivity to original solutions– Intellectual rigour– Objectivity– Methodical approach to their work– Concern about accurate measurements and calculations– Concern about using proper and precise language	<ul style="list-style-type: none">– Discipline– Independence– Concern for effectiveness– Concern for efficiency– Perseverance– Concern for a job well done– Sense of responsibility– Willingness to work hard– Willingness to cooperate effectively with others– Concern for health and safety– Respect for life and the environment– Attentiveness– Respect for themselves and others– Team spirit– International solidarity in dealing with major issues

Techniques

Often essential, techniques involve methodical procedures that provide guidelines for the proper application of theoretical knowledge. The techniques listed below are compulsory, like the compulsory concepts.

Techniques related to laboratory work

- Safely using laboratory or workshop materials and equipment
- Using observational instruments

Measurement techniques

- Checking the reliability, accuracy and sensitivity of measuring instruments (calibration, adjustment)
- Using measuring instruments
- Interpreting measurement results (significant figures, uncertainty related to measurements, errors)

Note: For mathematical operations involving measurements, the calculation of uncertainty is not required.

APPENDIX A –CONTEXTUALIZATION OF LEARNING

This Appendix sets out the compulsory concepts to be studied in relation to each of the general concepts covered in the Physics program, various possibilities for contextualization and the concepts examined in previous science and technology programs, all of which can help students assimilate the compulsory concepts for this program. Focusing on the study of phenomena and applications, the contextualization possibilities provide opportunities to synthesize learning by enabling students to apply previously acquired knowledge and skills and develop the three subject-specific competencies as well as the targeted concepts. These possibilities are suggested to support teachers in their work and provide for the integration of scientific, technological and mathematical knowledge. Other contexts can also be meaningful, and teachers should choose the contexts most likely to be of interest and benefit to their students.

Contextualization of the general concepts of physics and connections with concepts examined previously

Kinematics				
Compulsory concepts	<ul style="list-style-type: none"> – Reference systems – Uniform rectilinear motion <ul style="list-style-type: none"> • Relationship among position with respect to the point of origin, velocity and time • Displacement and distance • Average velocity and instantaneous velocity – Uniformly accelerated rectilinear motion <ul style="list-style-type: none"> • Relationship among acceleration, change in velocity and time • Relationship among acceleration, distance and time • Motion of a body on an inclined plane • Free fall – Motion of projectiles 			
Possibilities for contextualization	<ul style="list-style-type: none"> – Highway safety – Wave velocity – Fluid velocity – Movement in circulatory and lymphatic systems – Movement of living organisms – Projectiles (e.g. ball, ballistics, Millikan oil-drop experiment, rockets) – Sports training equipment – Distances on a microscopic and an astronomical scale – Measuring instruments (e.g. chronometer, stopwatch, radar speedometer, GPS, theodolite) – Means of transportation (e.g. automobile, train, sled, bicycle) – Elevator, cable car – Moving sidewalk, conveyor belt – Kinematic chain of machines 			
	The Material World	The Living World	The Earth and Space	The Technological World
Concepts examined previously	<ul style="list-style-type: none"> – Force – Types of forces – Equilibrium between two forces 	<ul style="list-style-type: none"> – Physical and behavioural adaptations – Types of joints – Circulatory system – Lymphatic system 	<ul style="list-style-type: none"> – Location of the Earth in the universe – Light (properties) – Solar system 	<ul style="list-style-type: none"> – Guiding controls – Types of motion – Motion transmission systems – Motion transformation systems – Speed changes – Machines and tools

Contextualization of the general concepts of physics and connections with concepts examined previously (cont.)

Dynamics				
Compulsory concepts	<ul style="list-style-type: none"> – Newton’s laws – Free-body diagram – Equilibrium and resultant of several forces – Force of friction – Gravitational force – Centripetal force – Gravitational acceleration 			
Possibilities for contextualization	<ul style="list-style-type: none"> – Parachuting – Muscle contraction – Balance and bathroom scale – Aerodynamics – Optimization of athletic performances – Biomechanics – Plate tectonics – Weightlessness – Geostationary satellite – Structures (e.g. tower, bridge) – Pulleys and pulley systems – Braking systems – Everyday objects – Mechanical jack, hydraulic spreader (i.e. jaws of life), nutcracker 			
	The Material World	The Living World	The Earth and Space	The Technological World
Concepts examined previously	<ul style="list-style-type: none"> – Types of forces – Equilibrium between two forces – Relationship between mass and weight 	<ul style="list-style-type: none"> – Physical and behavioural adaptations – Function of bones, joints and muscles 	<ul style="list-style-type: none"> – Internal structure of the Earth – Universal gravitation – Natural forms of energy – Earth-Moon system 	<ul style="list-style-type: none"> – Linking of mechanical parts – Guiding controls – Freedom of movement of a part – Adhesion and friction of parts – Materials and constraints – Simple machines – Effects of a force

Contextualization of the general concepts of physics and connections with concepts examined previously (cont.)

Transformation of energy				
Compulsory concepts	<ul style="list-style-type: none"> – Relationship among power, work and time – Mechanical energy – Hooke’s law 			
Possibilities for contextualization	<ul style="list-style-type: none"> – Wind turbine – Roller coasters and amusement park rides – Bungee jumping – Sports training equipment – Weightlifting – Trampolining – Biofuels – Hydroelectric and tidal power plants – Water wheel – Jackhammer – Shock absorbers – Pendulums – Catapults/slings 			
	The Material World	The Living World	The Earth and Space	The Technological World
Concepts examined previously	<ul style="list-style-type: none"> – Law of conservation of energy – Relationship among work, force and displacement – Effective force – Relationship between work and energy – Relation among potential energy, mass, acceleration and displacement – Mass and weight – Relationship among kinetic energy, mass and velocity 	<ul style="list-style-type: none"> – Input and output – Energy value of different foods – Ecosystem dynamics – Ecological footprint 	<ul style="list-style-type: none"> – Natural forms of energy – Flow of energy from the sun – Earth-Moon system (gravitational effect) 	<ul style="list-style-type: none"> – Simple machines – Motion transmission systems – Motion transformation systems

Contextualization of the general concepts of physics and connections with concepts examined previously (cont.)

Geometric optics				
Compulsory concepts	<ul style="list-style-type: none"> – Snell’s laws <ul style="list-style-type: none"> • Reflection <ul style="list-style-type: none"> - Incident and reflected rays - Angle of incidence and reflection • Refraction <ul style="list-style-type: none"> - Incident and refracted rays - Angle of incidence and refraction - Index of refraction – Images <ul style="list-style-type: none"> • Type of image (real, virtual) • Image characteristics (magnification, position) 			
Possibilities for contextualization	<ul style="list-style-type: none"> – Optometry – Photography – Optical illusions – Conjuring – Rear-view mirror – Vision in air and water – Optical phenomena (e.g. halos, mirages, rainbows) – Observation instruments (e.g. microscope, telescope, refracting telescope) – Albedo – Fibre optics – Optical sensors 			
	The Material World	The Living World	The Earth and Space	The Technological World
Concepts examined previously	<ul style="list-style-type: none"> – Deviation of light waves – Focal point of a lens 	<ul style="list-style-type: none"> – Cell components visible under a microscope – Sensory receptors (eye) 	<ul style="list-style-type: none"> – Greenhouse effect – Atmospheric layers – Seasons – Phases of the moon – Solar system 	<ul style="list-style-type: none"> – Standards and representations (diagrams and symbols)

APPENDIX B – EXAMPLES OF LEARNING AND EVALUATION SITUATIONS

The Train

1. Educational aim

This activity is intended to help students develop competency 1, *Seeks answers or solutions to problems involving physics*, by requiring them to solve an experimental problem.

2. Approximate time required

The activities require five 75-minute periods.

3. Broad area of learning and focus of development

Media Literacy

- Becoming familiar with methods for producing media documents

Simulating a falling train involves adjusting the speed at which the images are shown, which requires the strategic use of various information technologies.

4. Description of the activity

Introduction

A movie script calls for a train crossing a bridge to derail and fall into a river. However, the producers do not have the budget to film a real train accident, so the director decides to simulate it using a model train running over a bridge built on a studio set. According to the plans prepared by the set designers, the train will in fact fall from a height of only 1 m. For the director, the challenge is to find a way to film the accident so that on screen, it looks as though a real train is derailling and falling from a height of 125 m.

Drawing on your knowledge of and experience with kinematics, you must reproduce the motion of the falling train using a marble. The experimental apparatus you will have to construct and the data you gather must allow you to study the motion of the falling marble. You must also suggest the speed at which the scene should be shot.

Activities

The analysis of the motion of a projectile must highlight the independence of the two components of the motion, namely the uniform rectilinear motion and the uniformly accelerated rectilinear motion.

The students must set up an experimental apparatus that allows them to launch a marble at an initial horizontal speed, and then observe, study and formalize its motion. They should use an electronic stroboscope, a camera and a regular grid as a background.

5. Work expected of students

The students must produce a document stating how they solved the problem and include:

- an explanation of their initial understanding of the problem and the elements that facilitated their representation
- their plan
- the photograph taken, along with the measurements and calculations made to determine the actual distance travelled in each of the two dimensions
- graphs showing distance and speed as a function of time
- the calculations and strategies required for the simulation (shooting speed compared with projection speed)

6. Targeted subject-specific competency

Competency 1 – *Seeks answers or solutions to problems involving physics*

- Defines a problem
 - Provides an initial representation of the problem (identifies the train's trajectory, the force involved [force of friction can be ignored] and the type of motion imparted)
 - Identifies the initial data (height of actual and simulated fall)
 - Reformulates the problem in terms of scientific concepts (determines the shooting speed for a body in free fall)
- Develops a plan of action
 - Proposes a way to solve the problem
 - Determines the resources required (camera, stroboscope, kinematics concepts, etc.)
 - Plans the steps involved in the plan of action
- Carries out the plan of action
 - Carries out the required tests and tasks (photographs)
 - Gathers potentially useful data and observations (measurements based on the photographs)
- Analyzes his/her results
 - Makes connections between his/her results and the scientific concepts (analyzes the photographs, calculates speed and acceleration)
 - Judges the appropriateness of the solution or answer found (analyzes the experimental results, determines the shooting speed)

7. Targeted cross-curricular competencies

Solves problems; Uses information; Adopts effective work methods; Communicates appropriately

8. Resources (specified in the program content)*

Compulsory concepts

Compulsory concepts for the current year

- Uniform rectilinear motion
 - Relationship among position with respect to the point of origin, velocity and time
 - Displacement and distance
- Uniformly accelerated rectilinear motion
 - Relationship among acceleration, distance and time
- Motion of projectiles

Concepts from previous years

- Mass and weight

Methods

- Modelling, analysis, experimental method

9. Evaluation criteria

- Appropriate representation of the problem
- Development of a suitable plan of action
- Appropriate implementation of the plan of action
- Development of relevant conclusions, explanations or solutions

* Other resources presented in the program content (e.g. strategies, attitudes, techniques) can be taken into consideration.

Physical Attractions

1. Educational aim

This activity is intended to help students develop competencies 2 and 3, *Makes the most of his/her knowledge of physics* and *Communicates ideas relating to questions involving physics, using the languages associated with science and technology* through the examination of an application and its underlying scientific principles.

2. Approximate time required

The activity requires three 75-minute periods (excluding the documentary research that might be required).

3. Broad area of learning and focus of development

Career Planning and Entrepreneurship

– Familiarity with the world of work, social roles and occupations and trades

By elucidating the scientific principles used to ensure the technical operation of an application such as a roller coaster, students can meet stimulating challenges and learn about occupations and trades connected with school subjects or their immediate environment.

4. Description of the activity

Introduction

Attractions such as roller coasters are increasingly popular among thrill seekers. With their curves, hairpin bends and sudden drops, they are impressive structures whose operation remains a mystery for many people. What specific role do gravity, motion and speed play in this context?

You must provide explanations in this regard and highlight some specific features, basing your work on the laws, concepts and principles of mechanical physics. To do this, you must examine the features (using drawings or data) of three different roller-coaster circuits.

When analyzing the path and data for each roller coaster selected, you must identify the relationships among the maximum speed of the roller coaster train, the height of the track, the total rail length and the forces of friction. You can also analyze specific features of certain roller coasters, such as the minimum speed needed for a train to complete a loop-the-loop.

Activity

For this activity, the students must analyze various types of roller coasters using schematic diagrams or descriptive data.⁸

Example: Apollo's Chariot (Virginia, United States)



Total length (rails):	1488 m
Height:	51.8 m
Maximum speed:	117.5 km/h
Total duration:	135 s

The students must use their knowledge of mechanical physics to understand the overall operation of a roller coaster.

8. These data may be located easily on various Web sites about roller coasters around the world.

5. Work expected of students

The students must produce a document containing:

- a description of the features of three roller coasters
- a quantitative explanation of the physical laws governing the motion of the roller coaster trains on the rails
- an explanation of the differences between the theoretical results and the actual data

6. Targeted subject-specific competencies

Competency 2 – *Makes the most of his/her knowledge of physics*

- Examines a phenomenon or an application
 - Analyzes relevant data describing the paths of selected roller coasters
- Understands the principles of physics underlying the phenomenon or application
 - Takes into consideration and examines the concepts or principles connected with the transformation of energy, kinematics and dynamics
- Explains a phenomenon or an application from the standpoint of physics
 - Uses concepts intrinsic to mechanical energy, among other things, to present a line of reasoning and make calculations
 - Compares the theoretical results and the actual data to highlight the role played by friction

Competency 3 – *Communicates ideas relating to questions involving physics, using the languages associated with science and technology*

- Interprets scientific or technological messages
 - Reads and understands the information (diagrams, specifications, etc.)

- Produces and shares scientific or technological messages
 - Produces a document containing explanations, describing operations, etc.

7. Targeted cross-curricular competencies

Uses information; Communicates appropriately

8. Resources (specified in the program content)*

Compulsory concepts

Compulsory concepts for the current year

- Average velocity and instantaneous velocity
- Force of friction
- Centripetal force
- Free-body diagram
- Equilibrium and resultant of several forces
- Transformation of energy
 - Mechanical energy

Concepts from previous years

- Law of conservation of energy
- Relationship among potential energy, mass, acceleration and displacement
- Relationship among kinetic energy, mass and velocity
- Relationship between work and energy
- Relationship among work, force and displacement
- Mass and weight

Methods

- Observation method and analysis

* Other resources presented in the program content (e.g. strategies, attitudes, techniques) can be taken into consideration.

9. Evaluation criteria

Competency 2

- Formulation of appropriate questions
- Appropriate use of the concepts, laws and models of physics
- Relevant explanations
- Suitable justification of explanations

Competency 3

- Accurate interpretation of scientific or technological messages
- Appropriate production or sharing of scientific or technological messages
- Use of appropriate scientific and technological terminology, rules and conventions

APPENDIX C – DISTRIBUTION OF THE COMPULSORY CONCEPTS ASSOCIATED WITH THE MATERIAL WORLD, SECONDARY CYCLES ONE AND TWO⁹

General Education Path

Cycle One	Cycle Two (compulsory program)		Cycle Two (optional program)	Cycle Two (optional program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV	Secondary V
Science and Technology	Science and Technology		Environmental Science and Technology	Physics
Properties <ul style="list-style-type: none"> – Characteristic properties – Mass – Volume – Temperature – States of matter – Acidity/alkalinity 	Properties of matter <ul style="list-style-type: none"> – Characteristic physical properties <ul style="list-style-type: none"> • Melting point • Boiling point • Density • Solubility – Characteristic chemical properties <ul style="list-style-type: none"> • Reaction to indicators – Properties of solutions <ul style="list-style-type: none"> • Concentration (% , g/L) • Solute • Solvent 	Physical properties of solutions <ul style="list-style-type: none"> – Concentration (ppm) – Electrolytes – pH scale – Electrolytic dissociation – Ions – Electrical conductivity 	Physical properties of solutions <ul style="list-style-type: none"> – Concentration (ppm, mole/L) – Strength of electrolytes 	Kinematics <ul style="list-style-type: none"> – Reference systems – Uniform rectilinear motion <ul style="list-style-type: none"> • Relationship among position with respect to the point of origin, velocity and time • Displacement and distance – Uniformly accelerated rectilinear motion <ul style="list-style-type: none"> • Relationship among acceleration, change in velocity and time • Relationship among acceleration, distance and time • Average velocity and instantaneous velocity • Motion of a body on an inclined plane • Free fall – Motion of projectiles

9. For the full array of compulsory concepts associated with the four major areas covered in Secondary Cycles One and Two in the General Education Path, see Appendix D of the Environmental Science and Technology program. The same information pertaining to the Applied General Education Path is found in Appendix D of the Science and the Environment program.

Cycle One	Cycle Two (compulsory program)		Cycle Two (optional program)	Cycle Two (optional program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV	Secondary V
Science and Technology	Science and Technology		Environmental Science and Technology	Physics
Changes <ul style="list-style-type: none"> – Physical change – Chemical change – Conservation of matter – Mixtures – Solutions – Separation of mixtures 	Changes in matter <ul style="list-style-type: none"> – Physical changes <ul style="list-style-type: none"> • Dissolution • Dilution • Phase changes – Chemical changes <ul style="list-style-type: none"> • Decomposition and synthesis • Oxidation • Precipitation – Forms of energy (chemical, thermal, mechanical, radiation) <ul style="list-style-type: none"> • Particle model 	Chemical changes <ul style="list-style-type: none"> – Combustion – Photosynthesis and respiration – Acid-base neutralization reaction – Balancing chemical equations – Law of conservation of mass 	Chemical changes <ul style="list-style-type: none"> – Formation of salts – Stoichiometry – Types of bonds <ul style="list-style-type: none"> • Covalent • Ionic – Endothermic and exothermic reactions 	Dynamics <ul style="list-style-type: none"> – Newton's laws – Free-body diagram – Equilibrium and resultant of several forces – Force of friction – Gravitational force – Centripetal force – Gravitational acceleration
			Nuclear transformations <ul style="list-style-type: none"> – Nuclear stability – Radioactivity – Fission and fusion 	
Organization <ul style="list-style-type: none"> – Atom – Element – Periodic table – Molecule 	Organization of matter <ul style="list-style-type: none"> – Pure substance (compound, element) – Homogeneous and heterogeneous mixtures 	Organization of matter <ul style="list-style-type: none"> – Rutherford-Bohr atomic model – Lewis notation – Groups and periods of the periodic table 	Organization of matter <ul style="list-style-type: none"> – Neutron – Simplified atomic model – Nomenclature and notation rules – Polyatomic ions – Concept of mole – Avogadro's number 	
			Periodic table <ul style="list-style-type: none"> – Relative atomic mass – Atomic number – Periodicity of properties – Isotopes 	

Cycle One	Cycle Two (compulsory program)		Cycle Two (optional program)	Cycle Two (optional program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV	Secondary V
Science and Technology	Science and Technology		Environmental Science and Technology	Physics
	Fluids <ul style="list-style-type: none"> – Compressible and incompressible fluids – Pressure – Relationship between pressure and volume 	Electricity and electromagnetism <p>Electricity</p> <ul style="list-style-type: none"> – Electrical charge – Static electricity – Ohm’s law – Electrical circuits – Relationship between power and electrical energy <p>Electromagnetism</p> <ul style="list-style-type: none"> – Forces of attraction and repulsion – Magnetic field of a live wire 	Electricity and electromagnetism <p>Electricity</p> <ul style="list-style-type: none"> – Kirchoff’s laws – Electrical field – Coulomb’s law <p>Electromagnetism</p> <ul style="list-style-type: none"> – Magnetic field of a solenoid 	
		Transformation of energy <ul style="list-style-type: none"> – Law of conservation of energy – Energy efficiency – Distinction between heat and temperature 	Transformation of energy <ul style="list-style-type: none"> – Specific heat capacity – Relationship among work, force and displacement – Effective force – Relationship between work and energy – Relationship among potential energy, mass, acceleration and displacement – Mass and weight – Relationship among kinetic energy, mass and velocity 	Transformation of energy <ul style="list-style-type: none"> – Relationship among power, work and time – Mechanical energy – Hooke’s law

Cycle One	Cycle Two (compulsory program)		Cycle Two (optional program)	Cycle Two (optional program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV	Secondary V
Science and Technology	Science and Technology		Environmental Science and Technology	Physics
	Waves <ul style="list-style-type: none"> – Frequency – Wavelength – Amplitude – Decibel scale – Electromagnetic spectrum – Deviation of light waves – Focal point of a lens 			Geometric optics <ul style="list-style-type: none"> – Snell’s laws <ul style="list-style-type: none"> • Reflection <ul style="list-style-type: none"> - Incident and reflected rays - Angle of incidence and reflection • Refraction <ul style="list-style-type: none"> - Incident and refracted rays - Angle of incidence and refraction - Index of refraction – Images <ul style="list-style-type: none"> • Type of image (real, virtual) • Image characteristics (magnification, position)

Applied General Education Path

Cycle One	Cycle Two (compulsory program)		Cycle Two (optional program)	Cycle Two (optional program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV	Secondary V
Science and Technology	Applied Science and Technology		Science and the Environment	Physics
Properties <ul style="list-style-type: none"> – Characteristic properties – Mass – Volume – Temperature – States of matter – Acidity/alkalinity 	Properties of matter <ul style="list-style-type: none"> – Characteristic physical properties <ul style="list-style-type: none"> • Melting point • Boiling point • Density – Characteristic chemical properties <ul style="list-style-type: none"> • Reaction to indicators – Properties of solutions 		Physical properties of solutions <ul style="list-style-type: none"> – Solubility – Concentration (g/L, ppm, %, mole/L) – Electrolytes – pH scale – Ions – Electrical conductivity 	Kinematics <ul style="list-style-type: none"> – Reference systems – Uniform rectilinear motion <ul style="list-style-type: none"> • Relationship among position with respect to the point of origin, velocity and time • Displacement and distance – Uniformly accelerated rectilinear motion <ul style="list-style-type: none"> • Relationship among acceleration, change in velocity and time • Relationship among acceleration, distance and time • Average velocity and instantaneous velocity • Motion of a body on an inclined plane • Free fall – Motion of projectiles

Cycle One	Cycle Two (compulsory program)		Cycle Two (optional program)	Cycle Two (optional program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV	Secondary V
Science and Technology	Applied Science and Technology		Science and the Environment	Physics
Changes <ul style="list-style-type: none"> – Physical change – Chemical change – Conservation of matter – Mixtures – Solutions – Separation of mixtures 	Changes in matter <ul style="list-style-type: none"> – Physical changes – Chemical changes – Forms of energy – Particle model 	Chemical changes <ul style="list-style-type: none"> – Combustion – Oxidation 	Chemical changes <ul style="list-style-type: none"> – Precipitation – Decomposition and synthesis – Photosynthesis and respiration – Acid/base neutralization reaction – Salts – Balancing chemical equations – Law of conservation of mass – Stoichiometry – Types of bonds <ul style="list-style-type: none"> • Covalent • Ionic – Endothermic and exothermic reactions Physical changes <ul style="list-style-type: none"> – Dissolution – Dilution 	Dynamics <ul style="list-style-type: none"> – Newton's laws – Free-body diagram – Equilibrium and resultant of several forces – Force of friction – Gravitational force – Centripetal force – Gravitational acceleration
Organization <ul style="list-style-type: none"> – Atom – Element – Periodic table – Molecule 	Organization of matter <ul style="list-style-type: none"> – Pure substance (compound, element) – Homogeneous and heterogeneous mixtures 		Organization of matter <ul style="list-style-type: none"> – Lewis notation – Elementary particles (proton, electron, neutron) – Simplified atomic model – Relative atomic mass and isotopes – Nomenclature and notation rules – Polyatomic ions – Concept of mole 	

Cycle One	Cycle Two (compulsory program)		Cycle Two (optional program)	Cycle Two (optional program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV	Secondary V
Science and Technology	Applied Science and Technology		Science and the Environment	Physics
	Fluids <ul style="list-style-type: none"> – Compressible and incompressible fluids – Pressure – Relationship between pressure and volume 	Electricity and electromagnetism <p>Electricity</p> <ul style="list-style-type: none"> – Electrical charge – Static electricity – Ohm’s law – Electrical circuits – Relationship between power and electrical energy <p>Electromagnetism</p> <ul style="list-style-type: none"> – Forces of attraction and repulsion – Magnetic field of a live wire – Magnetic field of a solenoid – Electromagnetic induction 		
		Transformation of energy <ul style="list-style-type: none"> – Law of conservation of energy – Energy efficiency – Distinction between heat and temperature 	Transformation of energy <ul style="list-style-type: none"> – Relationship among work, force and displacement – Effective force – Relationship between work and energy – Relationship among potential energy, mass, acceleration and displacement – Relationship among kinetic energy, mass and velocity – Relationship among heat energy, specific heat capacity, mass and temperature 	Transformation of energy <ul style="list-style-type: none"> – Relationship among power, work and time – Mechanical energy – Hooke’s law

Cycle One	Cycle Two (compulsory program)		Cycle Two (optional program)	Cycle Two (optional program)
Secondary I and II	Secondary III	Secondary IV	Secondary IV	Secondary V
Science and Technology	Applied Science and Technology		Science and the Environment	Physics
	Waves <ul style="list-style-type: none"> – Frequency – Wavelength – Amplitude – Decibel scale – Electromagnetic spectrum – Deviation of light waves – Focal point of a lens 	Fluids <ul style="list-style-type: none"> – Archimedes' principle – Pascal's law – Bernoulli's principle Force and motion <ul style="list-style-type: none"> – Force – Types of forces – Equilibrium of two forces – Relationship among constant speed, distance and time – Distinction between mass and weight 		Geometric optics <ul style="list-style-type: none"> – Snell's laws <ul style="list-style-type: none"> • Reflection <ul style="list-style-type: none"> - Incident and reflected rays - Angle of incidence and reflection • Refraction <ul style="list-style-type: none"> - Incident and refracted rays - Angle of incidence and refraction - Index of refraction – Images <ul style="list-style-type: none"> • Type of image (real, virtual) • Image characteristics (magnification, position)

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