PROGRAM OF STUDY

PHYSICS

Subject Area: Mathematics, Science and Technology

Adult General Education

DBE
Diversified Basic Education

Québec

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Introduction

1.1 Contribution of the Subject to the Education of Adult Learners

As an integral part of the societies it helped to shape, science represents both an important aspect of their cultural heritage and a key factor in their development. The rapid emergence of large amounts of complex scientific knowledge and the proliferation of its applications presumes that people should possess a fund of specific knowledge, as well as strategies for freeing themselves of the constraints inherent in change. To achieve this freedom, they must see the achievements of science in perspective and understand the scope and limitations of scientific knowledge and its impact.

As one of the sciences, physics serves to broaden the general knowledge of adult learners and heighten their awareness of the role this knowledge can play in their ability to take informed decisions. The study of physics stimulates curiosity, imagination, the desire to explore and the pleasure of experimentation and discovery of new knowledge. It also responds to the learners' needs to understand, explain and create their environment. Physics is not the preserve of a small group of experts. The inventions and innovations it produces demonstrate the vital and essential role it plays in the development of societies, whether in the field of sports, transportation, energy resources, health or communications.

The Secondary V Physics program is a continuation of the science and technology programs offered in Secondary III and IV. It aims to consolidate and enrich the scientific knowledge of adults, and serves as a prerequisite to several pre-university and technical programs. The compulsory concepts are organized around general concepts related to geometric optics, kinematics, dynamics and the transformation of mechanical energy.

1.2 Approach to the Subject

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 processes, 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 comprehensive and complex visions. As we construct new knowledge, these theories and models are constantly being tested, modified and reorganized.

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. For this reason, it enjoys a special relationship with mathematics which provides the language through which physical phenomena are expressed.

1.3 Connections Between the Subject and the Other Elements of the Diversified Basic Education Program

The Physics program is connected to other components of the Diversified Basic Education Program such as the broad areas of learning, the cross-curricular competencies and the other subject areas.

1.3.1 Connections With the Broad Areas of Learning

The broad areas of learning are divided into five areas of life: *Health and Well-Being*, *Environmental Awareness and Consumer Rights and Responsibilities*, *Media Literacy*, *Career Planning and Entrepreneurship*, and *Citizenship and Community Life.* The Physics program uses learning situations pertaining to these broad areas to make learning more meaningful. In this way, adults are able to see that their learning is related to their various everyday activities.

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 to health, safety and comfort. An understanding of the forces controlled by the body and those that act upon the body can increase the efficiency and performance of movements, encourage the adoption of good work posture and shed light on the operation of some types of safety equipment. As well, geometric optics can explain the nature of angles, the dangers of blind spots and the uses and benefits of corrective and contact lenses.

Environmental Awareness and Consumer Rights and Responsibilities

Many advances in physics have changed consumer habits and led to various consequences for the environment. The situations examined in this area of learning lead students to analyze various applications of physics and their environmental impact. Issues related to transportation and energy efficiency are obvious examples. A greater awareness of such problems can help adult learners change their behaviour and use resources more responsibly.

Media Literacy

Adults use the various media to learn, obtain information and communicate. It is important that they develop a critical view of the information they receive and pass on. Movies, newspapers, television and various other electronic media address topics related to physics. A strong grounding in science is useful for assessing the reliability of information. In addition, electronic communication devices and their use can elicit adult learners' interest, encourage them to become more engaged in their learning, and boost their motivation. The situations examined in this broad area of learning highlight the importance of optics in the development of certain media, particularly in the fields of 3D imagery, holograms and barcode scanners.

Career Planning and Entrepreneurship

Many employment sectors require a grounding in scientific knowledge. For this reason, the tasks that the adults will carry out in this program offer opportunities for them to better understand the work of people employed in physics-related jobs. In this way, they will become acquainted with scientific work, develop their interests, measure their aptitudes for such trades and occupations and consider a career in this field.

Citizenship and Community Life

The competencies developed and the knowledge acquired in studying physics lead to a new perspective on social issues. Various life situations examined in this context, such as driving an automobile, can provide scenarios for learning about responsible citizenship. Adults can thus improve the quality of their participation in society in general.

1.3.2 Connections With the Cross-Curricular Competencies

The development of scientific literacy involves the acquisition and then development of three subject-specific competencies which, in turn, contribute to the acquisition of the more general cross-curricular competencies. These are grouped in several categories, reflecting different facets of the ability to act.

Intellectual Competencies

The learning situations in this program require that adult learners *use information* judiciously and question the reliability of their sources. The search for answers or solutions enables them to acquire problem-solving skills that they can then apply in other situations. They *use creativity* when they develop a plan of action or consider more than one way of conducting an experiment. Finally, they *exercise critical judgment* when analyzing scientific texts or presentations, or when evaluating the consequences of physics.

Methodological Competencies

The attention to precision associated with the methods used in physics requires that adult learners *adopt effective work methods*. They *use information and communications technologies*, which provide them with access to a wider variety of information sources and means of action.

Personal and Social Competencies

Adult learners who move from the abstract to the concrete or from decision to action, and who agree to take risks *achieve their potential*. The development of knowledge of physics is based on the sharing of ideas or points of view, and peer or expert validation. In short, the adults are required to *cooperate with others*.

Communication-Related Competency

The assimilation of new concepts and their representations through mathematical, scientific and technical language increases the adult learners' capacity to *communicate appropriately.* They must not only become familiar with the vocabulary, codes and conventions of physics, but must also learn to use them adequately.

1.3.3 Connections With the Other Subject Areas

Each subject has its own view of the world. From an interdisciplinary perspective, it is important to connect the learning achieved in physics with that acquired in other subjects. In this way, other subjects can shed light on physics just as physics can, in turn, help us gain a better understanding of other subjects.

Mathematics, Science and Technology

The programs of study in Mathematics, Science and Technology all belong to the same subject area as physics. They target the development of similar subject-specific competencies in terms of problem-solving, reasoning and communication. In the Diversified Basic Education program, this subject area is complemented by the Computer Science program.

Mathematics is closely related to the science programs. The vocabulary, graphics, notation and symbols used in mathematics constitute a language of rigorous precision, of which physics takes advantage. Mathematics is frequently used in developing or constructing models and in problem solving, both practical and theoretical.

Furthermore, physics gives concrete form to certain types of mathematical knowledge, in particular variables, proportional relationships and vectors. It provides meaningful contexts for the study of measurement and statistics.

The development of knowledge in physics has benefited from the rise of computer science, which has brought with it higher-performance tools for finding information, processing data, presenting and sharing results, etc. Conversely, physics contributes to computer science by providing contexts for application that stimulate the creation and enhancement of new products.

Languages

The Languages subject area provides essential tools for developing scientific competencies. In physics, an adult learner who interprets information or who describes or explains a phenomenon makes use of competencies developed in the subject area of languages. Physics presents the student with an opportunity to use precise vocabulary and to understand the importance of rigorously accurate language.

Since English is used worldwide in scientific communication, the adult learner who possesses a command of English, as well as of a second or third language, has access to more numerous and diverse sources of information.

Social Sciences

The advances made by science occur in a social and historical setting. The historical perspective places scientific progress in context, enabling adults to appreciate the importance of progress and measure its implications. In social terms, wealth (and its method of distribution) influences both the development of societies and the advancement of physics.

Since societies are dependent on the tools and means at their disposal, the study of physics enables students to see their history and development in a different light.

Arts Education

The subjects in Arts Education contribute substantially to the development of creativity. The Physics program draws on this creativity for solving problems. In turn, physics contributes to the arts. For example, a good understanding of kinematics and dynamics helps to improve the artistic performance of dancers and acrobats. Also, applications of geometric optics enhance the presentation of stage sets and lighting.

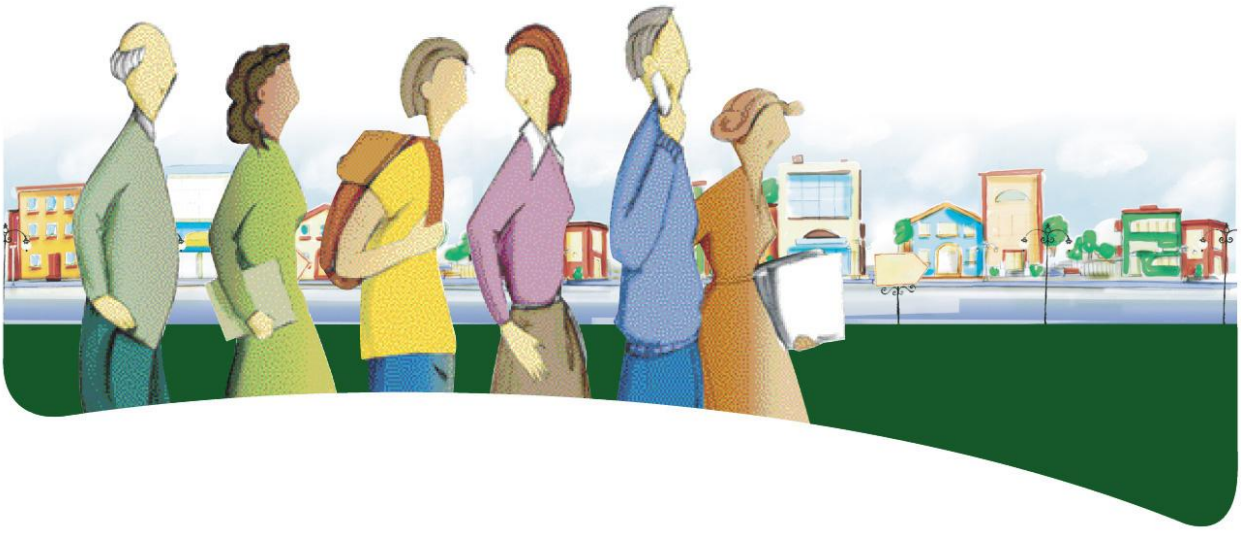
Personal Development

The Physics program takes into account reflections related to personal development when it encounters questions of an ethical nature, such as the issues involved in selecting a speed limit for public roads. As well, the program enriches the subject area of personal development by including its principles. For example, the creation of new applications that encourage the practice of sports could contribute to the improvement of people’s health.

Career Development

The fields of application for physics touch on numerous sectors of activity and can be associated with the occupations in these sectors. The learning situations proposed in the physics courses give adult learners ideal opportunities to explore different work activities and their related occupations. In return, the activities associated with the Career Development program can help adult learners discover an interest in scientific questions in the field of physics.

Chapter 2



Pedagogical Context

2.1 Learning Situations

Learning situations help adult learners construct and mobilize knowledge and develop subject-specific and cross-curricular competencies. Related to a specific context, they present a problem to be solved or an issue to be examined. They involve one or more tasks leading to the production of a specific piece of work.

Through their context, learning situations help achieve the educational aim of the broad area of learning to which they are related. *Meaningful*, *open* and *complex* learning situations confer more meaning on the knowledge acquired, and foster the integration of subject-specific content and key features of the competencies. A learning situation is *meaningful* when it focuses on adult learners' interests as they relate to current events, major social issues, or scientific or technological achievements that affect everyday life. It is *open-ended* when it enables adult learners to choose a method and explore several possible solutions. It is *complex* when it requires adult learners to mobilize a greater number of resources and provides them with the opportunity to apply more than one competency.

Although the use of learning situations is compulsory, none of the examples given in the courses is prescribed. The same applies to examples of tasks. Teachers create or choose those that they deem appropriate.

2.2 Families of Learning Situations

Learning situations that share a resemblance because of the types of tasks they include constitute a family. Whatever their level of complexity, situations in the same family foster the transfer of learning. The Physics program consists of two families of learning situations: *Research* and *Expertise*.

Research

Learning situations in the *Research* family consist of tasks aimed at solving a problem in physics. Such situations require creativity. Adult learners establish their action plan, select the tools they need and use them to solve the problem. They present the results of their work and, if applicable, propose new hypotheses or solutions. Learning situations in the *Research* family involve the use of laboratory equipment and techniques specific to physics.

Expertise

Learning situations in the *Expertise* family involve tasks that require the adults to consider a physical phenomenon or an application of physics. They are then required to identify the scientific concepts at play, determine how they work together and explain them. To do so, the adult learners must make use of all available information and draw upon concepts, laws, theories or models from the field of physics. This type of analysis sometimes leads to the use of measurement and observation materials and techniques common in physics, while the study of the application can sometimes lead to using tools and techniques of graphic representation or dismantling procedures assisted by technology. In this way, adults can formulate a clear explanation of the phenomenon or the elements of physics involved in the application.

The learning situations in the *Research* and *Expertise* families allow for the construction of knowledge, the mobilization of resources, the implementation of investigative processes and the development of the competencies in the Secondary V Physics program.

The families of learning situations are compulsory. Every course must include situations drawn from the two families indicated above.

2.3 Educational Resources

In developing their competencies, adults draw on different resources that can be classified as personal, conceptual, informational, material, institutional or human.

Personal resources include knowledge, skills, strategies, attitudes and techniques that adult learners have already acquired. Conceptual resources comprise knowledge acquired in different academic subjects, while informational resources include textbooks, reference documents and any other materials used in searching for information. Material resources can include many types of instruments and objects. Institutional resources refer to public or parapublic organizations, industries or local businesses, and any other community resource. Teachers and classmates are the most immediately accessible human resources. Laboratory technicians are good resources, especially where laboratory safety is concerned. As needed, adult learners can also consult teachers in other subjects or different experts.

Chapter 3

Subject-Specific Competencies

3.1 How the Subject-Specific Competencies Work Together

In the Diversified Basic Education Program, a competency is defined as **the ability to act effectively by mobilizing a range of resources**. It is demonstrated in contexts of a certain complexity, and the degree to which it is mastered may increase throughout a person's education and even lifetime. The Secondary V Physics program targets the development of three subject-specific competencies. These competencies are associated with three complementary dimensions of science: practice and methodology, theory, and communication.

The first competency, *Seeks answers or solutions to problems involving physics,* emphasizes the methodology used to solve problems in science. It focuses on the mobilization of concepts and techniques associated with physics, primarily within the context of an investigative process that most often takes place in a laboratory.

The second competency, *Makes the most of his/her knowledge of physics*, stresses the ability to conceptualize and to transfer learning, especially when analyzing phenomena or applications. It involves the assimilation of concepts related to physics that enable us to understand and explain these phenomena and applications.

The third competency, *Communicates ideas relating to questions involving physics, using the languages associated with science and technology,* is demonstrated by the knowledge and use of specialized terminology and symbols. It draws on the various languages used in physics that are essential to sharing information and to interpreting and producing messages of a scientific nature.

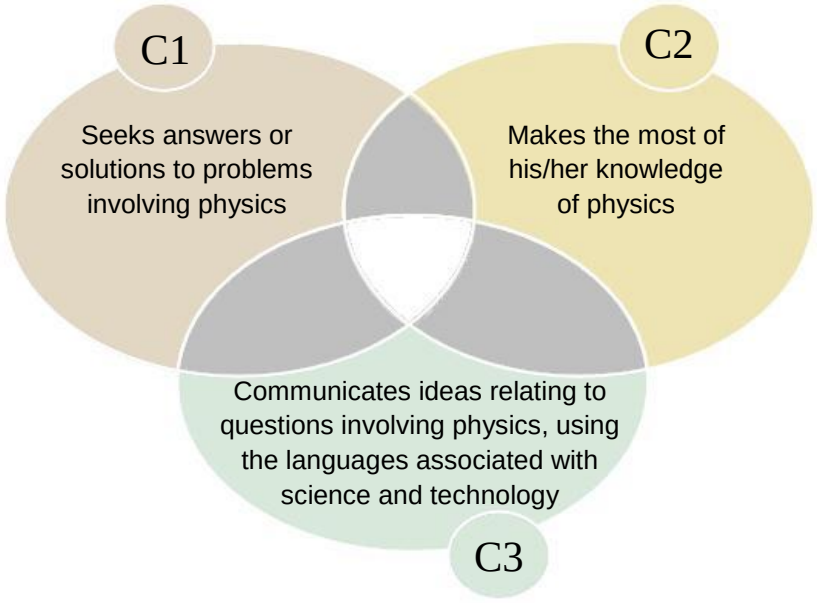


Diagram 1 - How the Subject-Specific Competencies Work Together

The three competencies are interrelated in various ways and are developed in synergy. For example, adult learners cannot seek answers to problems involving physics without learning and applying specific knowledge and mastering communication strategies. Likewise, to make the most of physics knowledge requires using a language shared by the members of the scientific community. This knowledge is applied repeatedly in solving problems.

The Three Aspects of Demonstrating a Competency

A competency is demonstrated through action and is expressed in the satisfactory execution of tasks in a given context. There are three aspects to its demonstration: contextualization, mobilization of resources and reflection.

First of all, applying a competency requires a thoughtful reading of the characteristics of the context, in other words, contextualization. Second, adult learners must take into account any constraints inherent in the context, make a plan and mobilize a set of resources. Lastly, they must be able to explain how they went about mobilizing an appropriate set of resources to act in a given situation. The concept of competency therefore involves the ability to think about the steps taken to carry out tasks and solve problems. This reflection process allows adult learners to better adjust their actions and the teachers to adjust their interventions.

Interactions Between the Aspects of Demonstrating a Competency

The three aspects of demonstrating a competency are not a simple juxtaposition of concepts. They interact in a dynamic way:

- The interaction between contextualization and the mobilization of resources involves re-using and recombining the same knowledge in a number of ways, depending on the contexts.
- The interaction between reflection and contextualization enables the adults to perceive more clearly the characteristics of the situation and to better understand its constraints.
- The interaction between reflection and the mobilization of resources primarily involves the reorganization of knowledge. It is also related to any type of analysis that enables adult learners to identify the strengths and weaknesses of the course of action taken.

Each of these interactions contributes to the transfer of learning. The following diagram illustrates how the different aspects of demonstrating a competency work together.

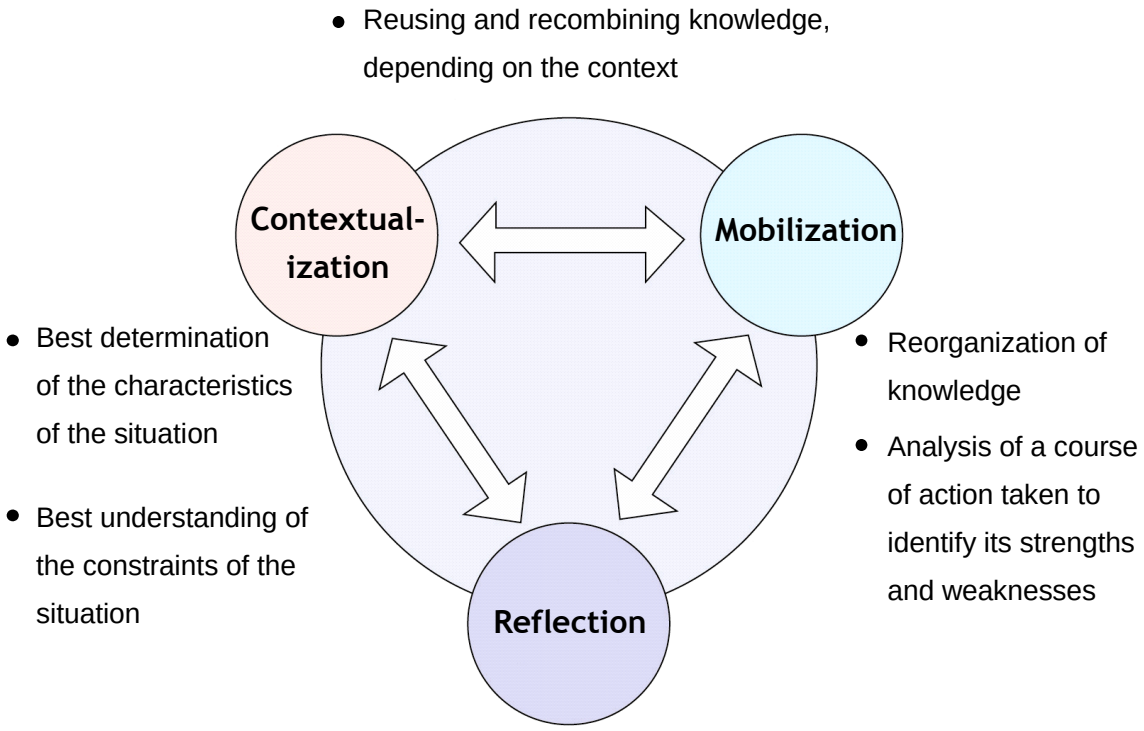


Diagram 2 - Interactions Between the Aspects of Demonstrating a Competency

3.2 Competency 1: Seeks answers or solutions to problems involving physics

3.2.1 Focus of the Competency

Like other science subjects, physics is characterized by a rigorous approach to the search for answers or solutions to the problems belonging to its field. Its type of reasoning is based on investigative processes that require the mobilization of strategies, techniques and concepts that are grounded in science. The structuring of these resources implies that the adult learner is capable of selecting and adapting them to a particular situation. It is by exploring various avenues, testing hypotheses, receiving feedback and reformulating a problem that the adult learner will finally be able to construct a satisfying solution. In the majority of cases, this competency involves carrying out experiments and requires the use of specialized materials.

The first aspect of this competency becomes evident when the adult learner develops a way of representing a problem based on meaningful indicators and relevant elements. This initial

representation of the problem may require several adjustments and be used to explore various problem-solving scenarios.

After selecting one of these scenarios, adult learners develop a plan of action that takes into account applicable material constraints and limitations, as well as the resources available to them to solve the problem.

The adult learners carry out their plan of action, taking care to record all observations that may be useful to them at a later point. They may even, in certain cases, carry out trials. New data may then require them to adapt their initial plan or search for more appropriate solutions.

The data collected must then be analyzed. The adult learners identify tendencies and significant relationships, provide relevant explanations and draw conclusions. If applicable, they make a judgment of the accuracy of their results according to the discrepancy they observe in comparison with an acceptable conventional value. These comparisons enable them to validate or invalidate their hypothesis and judge the relevance of their answer. In their report, the adult learners take care to use the significant figures, together with the margin of error.

3.2.2 Key Features and Manifestations of the Competency

- **Defines a problem**
  - Determines the elements that seem relevant
  - Determines the relationships between the different elements
  - Reformulates the problem in terms of physics concepts
  - Formulates realistic hypotheses or possible solutions

- **Develops a plan of action**
  - Chooses a hypothesis or a solution
  - Determines the necessary resources
  - Plans the steps involved in implementing the plan of action

- **Carries out the plan of action**
  - Handles equipment and substances and carries out planned operations
  - Gathers potentially useful data or observations
  - Adjusts the plan of action or its implementation, if necessary

- **Analyzes his/her results**
  - Processes the data gathered or his/her observations
  - Looks for significant patterns or relationships

- Makes connections between his/her results and physics concepts
- Judges the appropriateness of the answer or solution found
- Formulates new hypotheses or solutions, if applicable

3.2.3 Development of the Competency

In order to foster development of the competency *Seeks answers or solutions to problems involving physics*, teachers propose learning situations that are based on an investigative process and that encourage the students' involvement in problem solving.

Physics is the search for answers to questions about phenomena that are governed by laws. It makes use of an investigative process that generates models or theories that serve as the basis for understanding these phenomena.

In order to carry out the plan of action, it is necessary, in most cases, to perform a certain number of tasks in the laboratory. Review activities performed throughout the process are focused on the procedures chosen and favour a better use of the steps of these procedures and their related techniques and strategies, as well as their adaptation to different contexts.

3.3 Competency 2: Makes the most of his/her knowledge of physics

3.3.1 Focus of the Competency

Physics is indispensable for understanding many of the issues in the world today. People who are able to take advantage of their knowledge in this field are better equipped to participate in society and understand their role in it more clearly. To acquire this knowledge, adult learners must use methods of reasoning and investigative processes that they have studied in their physics classes.

The first manifestation of this competency appears when the adult learners examine the context of the phenomenon or application under study. They consider the elements that seem pertinent, identify the physics principles involved and form a representation of the phenomenon or application by referring to concepts.

The adult learners who engage in this analysis demonstrate their understanding of the principles involved by describing them qualitatively or quantitatively. They establish the relationships between them using the concepts, laws, theories and models that underlie them. This work can be the result of certain tasks performed in the laboratory.

In order to explain a phenomenon or an application from the standpoint of physics, competent adult learners refer to the relevant concepts, laws, theories or models. They make use of scientific and

mathematical formalism to justify their explanations, as needed. They present their results together with an explanation of their course of action and how they have mobilized their resources. They take care to make proper use of significant figures, not forgetting the degree of uncertainty associated with them. Since the same principles are valid for several phenomena or applications, they may be called upon to transfer or adapt their explanation to other contexts.

3.3.2 Key Features and Manifestations of the Competency

- **Identifies the principles of physics underlying a phenomenon or application**
  - Considers the elements of the context
  - Identifies the principles of physics
  - Creates a representation of the phenomenon or application, based on physics concepts

- **Analyzes the principles of physics underlying a phenomenon or application**
  - Describes the principles of physics underlying a phenomenon or application qualitatively or quantitatively
  - Uses concepts, laws, theories or models to establish the relationships between physics principles underlying a phenomenon or application

- **Explains a phenomenon or an application from the standpoint of physics**
  - Develops an explanation based on scientific concepts, laws and models of physics
  - Justifies his/her explanation using scientific and, if necessary, mathematical formalism
  - Adapts the proposed explanation to other contexts, if applicable

3.3.3 Development of the Competency

To enable adult learners to develop the competency *Makes the most of his/her knowledge of physics,* teachers propose learning situations involving an application or phenomenon related to one or more principles of physics.

To satisfy the need for understanding a phenomenon or application, it is necessary to construct new knowledge and to relate this to the knowledge already constructed. All this knowledge is used to explain the use of the principles of physics in the manufacture or operation of the application or, again, to describe and explain the phenomenon.

Review activities performed throughout the process involve assimilating knowledge, using resources and adapting them to the requirements of different contexts.

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

3.4.1 Focus of the Competency

Communication plays an essential role in the acquisition of scientific knowledge. This knowledge is constructed based on a set of common meanings, the exchange of ideas and the negotiation of points of view. This competency cannot be developed in isolation from the other two competencies in the program, to whose development it contributes.

The interpretation and production of messages bearing on physics issues involves using the vocabulary and symbols specific to physics, as well as tables, graphs, diagrams, models and mathematical equations. In fact, there are standards and conventions governing the writing of protocols and reports. Adult learners take these into account when they prepare for a task, search for information, establish a plan of action, write a report or provide an explanation. They also verify the reliability of the sources they consult and respect the intellectual property rights of persons whose ideas they borrow or whose results they make use of.

3.4.2 Key Features and Manifestations of the Competency

- **Interprets scientific or technological messages**
  - Places the message in context
  - Makes sure the sources are reliable
  - Selects the elements needed to interpret the message
  - Grasps the precise meaning of words or statements
  - Establishes connections between concepts and their graphic or symbolic representations

- **Produces scientific or technological messages**
  - Structures his/her message
  - Uses scientific and technological vocabulary
  - Uses the symbolic and graphical languages associated with science and technology
  - Adheres to the established standards and conventions for the different languages
  - Demonstrates rigour and coherence
  - Respects intellectual property rights

3.4.3 Development of the Competency

To enable adult learners to develop the competency *Communicates ideas relating to questions involving physics, using the languages associated with science and technology*, teachers propose learning situations involving various forms of presentation and the use of precise scientific and technological vocabulary. This helps them to make connections between various representations of concepts.

The learning situations related to the first and second competencies generally offer the adult learner an opportunity to develop this third competency. In fact, this competency is needed to read or present a project, write and analyze a report, develop or carry out a protocol, and study or create a model. Situations in which adult learners share their findings or seek answers to questions foster the development of their ability to communicate in a language adapted to science and technology.

Review activities performed throughout the process focus on the resources and techniques that form the basis of communication, on their use and on their adaptation to the requirements of the context.

3.5 Processes

To solve a problem or study a phenomenon or application, adult learners use an investigative process. The following diagram illustrates recognized scientific investigative processes.

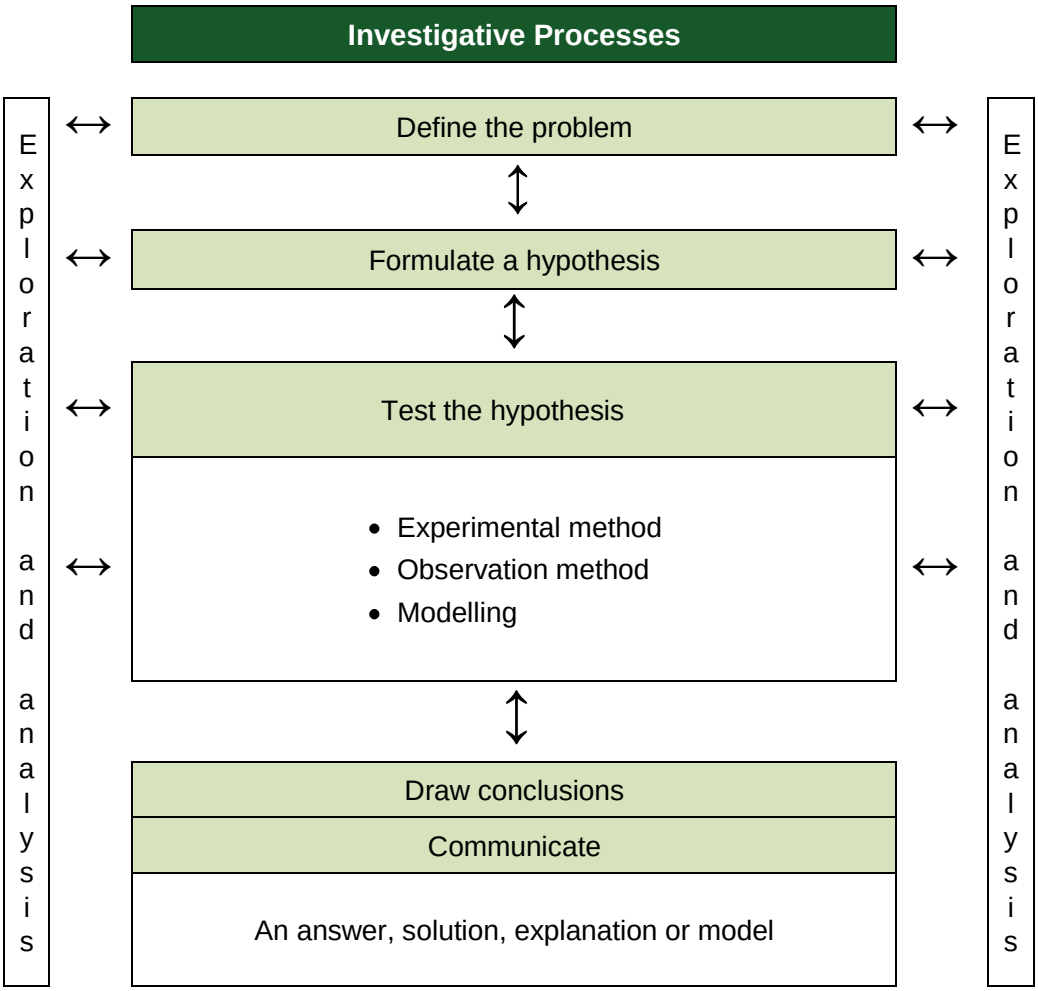


Diagram 3 - Investigative Processes

As suggested by the vertical double-headed arrows, investigative processes are rarely linear. Before adult learners are able to draw conclusions and communicate their solution, they may return several times to a previous step. The horizontal double-headed arrows refer to the exploration and analysis strategies used to proceed more effectively towards a conclusion. Examples of each of the strategies and each of the steps are given in Appendixes 1 and 2.

The *investigative processes* encompass the different methods mentioned in the Secondary Cycle Two program: the experimental method, modelling and the observation method. As illustrated in the previous diagram, these processes diverge only at the hypothesis testing stage; that is why, in this program, they are grouped together under the general heading “Investigative Processes.” The tables in Appendix 3 present in detail each of the methods used to test hypotheses.

The Physics program gives adult learners the opportunity to use all these methods, although the experimental method is the one most in evidence. It is called upon explicitly in the development of Competency 1. This emphasis on the experimental method helps to illustrate, on the one hand, the difficulties involved in scientific research and, on the other hand, the work accomplished by scientists who have been able to develop different physics laws and theories in spite of the occasional lack of precision in the measuring instruments they used.

Chapter 4

Subject-Specific Content

4.1 Knowledge

The Physics program aims to consolidate and enrich scientific and technical knowledge that is based on the development of competencies, the construction of knowledge and the mobilization of resources in connection with various elements of the program: compulsory concepts, processes, techniques and cultural references. In addition, it aims to train users of physics who are aware of its implications and to prepare some of them for careers in the field of science and technology.

4.1.1 Compulsory Concepts

The compulsory concepts in the Physics program are connected to *The Material World* and are related to geometric optics, kinematics, dynamics and the transformation of mechanical energy. A list can be found in Chapter 5 in the course table. These are repeated in Chapter 6 under the Subject-Specific Content heading for each course, along with the orientations and a list of knowledge to be acquired.

4.1.2 Techniques

Techniques involve methodical procedures that provide guidelines for the proper application of theoretical knowledge. They fall into two categories: techniques related to laboratory work and measurement techniques.

Many of these techniques require the use of instruments and the handling of objects. Safety and the use of safety equipment must be a constant concern for all those using such techniques.

Summary of Techniques
Techniques related to laboratory work
- Safely using laboratory materials and equipment - Using observational instruments
Measurement techniques
- Checking the reliability, accuracy and sensitivity of measuring instruments - Interpreting measurement results (significant figures, measurement errors)

Table 1 - Summary of Techniques

4.2 Cultural References

Cultural references are particularly meaningful when it comes to scientific literacy. They contribute to the enrichment of learning situations by rooting them in social and cultural reality. They may include technical objects, technological systems, technological procedures, products, scientists of both sexes, community resources, human activities and events related to the learning content of the courses. A list of cultural references is given for each course in Chapter 6.

The knowledge related to cultural references forms part of the subject-specific content to be mobilized in this program of study. While the use of references is compulsory, the list of examples is provided for illustration purposes only. The established list is not exhaustive.

Chapter 5

Organization of the Courses in the Program

5.1 Introduction to the Courses

The Two Physics Courses

The Physics program is composed of two courses, PHS-5061-2 and PHS-5062-2. The courses must be taken in the order indicated. This sequence is imposed by the progression of expectations in the context of an investigative process that includes experimentation, and by certain concepts in kinematics that are used in the study of dynamics.

Course PHS-5061-2, *Kinematics and Geometric Optics*, deals with phenomena and applications related to the trajectory of light rays when they meet a dioptre or the motion of a body regardless of the cause. Laboratory work consolidates the learning related to experimentation that was acquired in Secondary III and IV.

Course PHS-5062-2, *Dynamics and Transformation of Mechanical Energy*, is devoted to the study of forces acting on bodies (cause of motion) and the principle of the conservation of mechanical energy. Laboratory activities provide for the autonomous application of skills related to experimentation.

The following table presents the content of the courses in the Physics program.

Courses		
Title	**Hours/ Credits**	**Compulsory Concepts**
PHS-5061-2 ***Kinematics and Geometric Optics***	50 hours 2 credits	• Kinematics - Reference systems - Uniform rectilinear motion - Uniformly accelerated rectilinear motion - Motion of projectiles • Geometric optics - Snell's laws - Images
PHS-5062-2 ***Dynamics and Transformation of Mechanical Energy***	50 hours 2 credits	• Dynamics - Newton's laws - Free-body diagram - Equilibrium and resultant of several forces - Effective force - Force of friction - Gravitational force - Centripetal force - Hooke's law - Gravitational acceleration • Transformation of energy - Relationship between power, work and time - Mechanical energy - Relationship between energy, the spring constant and the length variation of a helical spring - Relationship between work, force and displacement - Relationship between work and energy - Relationship between potential energy, mass, acceleration and displacement - Relationship between kinetic energy, mass and velocity

Table 2 - Program Courses

Chapter 6

Courses

6.1 Organization of Course Information

This chapter contains a detailed description of each of the courses in the Physics program, presented under the following headings:

Headings
Introduction
Subject-Specific Competencies
Processes
Cross-Curricular Competencies
Subject-Specific Content
Families of Learning Situations
Broad Areas of Learning
Example of a Learning Situation
End-of-Course Outcomes
Evaluation Criteria for Competencies Targeted by the Course

Course
PHS-5061-2
Kinematics and Geometric Optics

Physics

INTRODUCTION

The course entitled *Kinematics and Geometric Optics* is aimed at enabling adult learners to function effectively in situations from the *Research* and *Expertise* families where they may be describing the motion of objects or representing the deviation of the trajectory of light using geometry.

The adult learners enrolled in this course study phenomena and technical applications related to kinematics, reflection and refraction of light, and look for answers to related problems. They construct knowledge about the vectorial nature of certain parameters, such as velocity, acceleration and displacement, as well as the behaviour of light reflected by a mirror or passing through a dioptometer. This knowledge leads them to induce the equations that describe uniform rectilinear motion, uniform acceleration, the trajectory of light and the characteristics of an image. They can then explain some natural phenomena, such as rainbows, mirages and falling objects, and understand the function of a technological application such as a Newtonian telescope or an accelerometer. Furthermore, since experimentation and modelling occupy a central place in the development of competencies and the construction of knowledge related to the concepts in the course, the adult learners carry out several laboratory activities that help them consolidate their learning from Secondary III and IV about techniques and methods.

By the end of this course, in *Research* and *Expertise* situations, adult learners will be able to:

- ✓ carry out an investigative process that includes experimentation to solve a kinematic or geometric optics problem
- ✓ analyze a phenomenon or technological application involving the motion of an object or the deviation of light through a dioptometer or a mirror
- ✓ predict the maximum range and height of a projectile or the position and characteristics of an image formed by a mirror or a lens
- ✓ prepare an experimental protocol, according to guidelines, to answer a question related to the motion of an object or the deviation of light
- ✓ write a laboratory report, using an outline, related to kinematics or geometric optics

SUBJECT-SPECIFIC COMPETENCIES

The following table lists, for each competency, the key features studied in the course. The manifestations of the key features are presented in Appendix 4.

Competency 1 Seeks answers or solutions to problems involving physics	Competency 2 Makes the most of his/her knowledge of physics	Competency 3 Communicates ideas relating to questions involving physics, using the languages associated with science and technology
▪ Defines a problem ▪ Develops a plan of action ▪ Carries out the plan of action ▪ Analyzes his/her results	▪ Identifies the principles of physics underlying a phenomenon or application ▪ Analyzes the principles of physics underlying a phenomenon or application ▪ Explains a phenomenon or an application from the standpoint of physics	▪ Interprets scientific or technological messages ▪ Produces scientific or technological messages

PROCESSES

The investigative processes enable adult learners to solve problems involving the principles of physics and to study an application or phenomenon related to kinematics or geometric optics. The following are the steps in an investigative process:

- Define the problem
- Formulate a hypothesis
- Test the hypothesis
- Draw conclusions and communicate

The most appropriate investigative processes for this course are the observation method, the experimental method and modelling. It is during hypothesis verification that these methods become distinguishable. Section 3.5 and Appendixes 1 to 3 present these investigative processes, with their respective characteristics.

In this course, laboratory experiments require adult learners to carry out specific tasks in accordance with the following limitations and instructions.

Experimental Method	
Steps	**Tasks**
1. Plans an experiment	With guidance, the adult learner: - writes up an experimental protocol for physics - selects the materials required to do an experiment - identifies the applicable safety rules, the constant parameters and the parameters to be investigated (independent variable, dependent variable)
2. Conducts the experiment	The adult learner: - follows the experimental protocol - collects data, keeping in mind the factor of experimental error - applies the appropriate safety rules
3. Interprets the results	In writing up a report, using an outline, the adult learner: - takes significant figures into account when processing the data - analyzes the results - identifies the sources of error - discusses the results - writes the conclusion, making connections with the problem in question

CROSS-CURRICULAR COMPETENCIES

The cross-curricular competencies supplement the subject-specific competencies. The development of one contributes to the development of the others. Course PHS-5061-2 allows for putting all the cross-curricular competencies into practice. Some of them, indicated in grey shading in the table below, are especially targeted in the sample learning situation that will be presented in the last part of the course.

Cross-Curricular Competencies			
Intellectual	**Communication-Related**	**Personal and Social**	**Methodological**
Uses information	Communicates appropriately	Achieves his/her potential	Adopts effective work methods
Solves problems		Cooperates with others	Uses information and communications technologies
Exercises critical judgment			
Uses creativity			

SUBJECT-SPECIFIC CONTENT

A) KNOWLEDGE

The compulsory concepts and techniques are presented in the tables in the following two sections.

1. Concepts

The knowledge written in italics has been acquired in the science and technology programs and must be mobilized again in this course.

The Material World	
General concept: Kinematics Everywhere around us and inside us, things are vibrating and moving around in relation to each other. There is no universal reference system to describe motion; motion exists relative 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. 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, if we interpret a single graph, we can deduce the other two. Changes in position, velocity and acceleration are regarded as vector quantities, and adult learners must master operations involving them. Complex motion, such as that of projectiles, is decomposed into simpler motions (vectorial components).	
COMPULSORY CONCEPTS	**PREVIOUSLY ACQUIRED KNOWLEDGE**
Uniform rectilinear motion - Relationship between speed, distance and time Change in velocity	• *Describes qualitatively the relationship between speed, distance and time* • *Applies the mathematical relationship between constant speed, distance and time* ($v = d/\Delta t$) • *Uses systems that allow for changes in the design of technical objects*
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Reference systems Uniform rectilinear motion - Relationship between the position with respect to the point of origin, velocity and time - Displacement and distance	• Chooses a reference system suited to the situation • Provides a qualitative explanation and uses a graph to illustrate the relationship between the position of an object with respect to its point of origin (displacement), its velocity and the time during which it is in motion • Applies the mathematical relationship between position with respect to the point of origin (displacement), velocity and time ($\Delta d = v \Delta t$) in a given situation • Distinguishes displacement from distance travelled

Kinematics (cont.)	
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Uniformly accelerated rectilinear motion	
- Relationship between acceleration, change in velocity and time	• Provides a qualitative explanation and uses a graph to illustrate the relationship between the acceleration of a body, the change in its velocity and the time during which this change occurs • Applies the mathematical relationship between acceleration, change in velocity and change in time ($a = \Delta v/\Delta t$) in a given situation
- Relationship between acceleration, distance and time	• Provides a qualitative explanation and uses a graph to illustrate the relationship between the acceleration of a body, the distance it travelled and the time interval • Applies the mathematical relationship between acceleration, the distance travelled and time ($\Delta d = v_i \Delta t + 1/2\ a\ \Delta t^2$) in a given situation
- Average velocity and instantaneous velocity	• Explains the distinction between average velocity and instantaneous velocity • Determines the instantaneous velocity of an object • Determines the average velocity of an object
- Free fall	• Provides a qualitative explanation and uses a graph to illustrate the motion of a free-falling body (position, displacement, average velocity, instantaneous velocity, acceleration) • Determines the position, displacement, average velocity, instantaneous velocity or acceleration of a free-falling body
- Motion of a body on an inclined plane	• Provides a qualitative explanation and uses a graph to illustrate the motion of a body on an inclined plane (position, displacement, average velocity, instantaneous velocity, acceleration) • Determines the position, displacement, average velocity, instantaneous velocity or acceleration of a body on an inclined plane
Motion of projectiles	• Explains the motion of a projectile (combination of uniform rectilinear motion and uniformly accelerated rectilinear motion) • Determines the position, displacement or instantaneous velocity of a projectile, or the time elapsed

General concept: Geometric optics

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 and lenses. Geometric optics is based on the concept of light rays, a theoretical construct indicating the direction in which light travels.

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. One of these laws can be used to calculate the refractive index of each transparent medium through which light travels.

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. The experiments they carry out will help adult learners 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.

Note: Magnifying power will not be studied.

COMPULSORY CONCEPTS	PREVIOUSLY ACQUIRED KNOWLEDGE
Deviation of light waves	• *Describes how light rays are deviated by a plane reflective surface* • *Determines the angle of reflection of a light ray on the surface of a plane mirror* • *Describes how light rays are deviated when they pass through the surface of a translucent convex or concave surface*
Focal point of a lens	• *Determines the focal point of concave or convex lenses* • *Describes the relationship between the focal point of a lens and the degree of deviation of light rays in different situations (e.g. accommodation of the crystalline lens, choice of corrective lenses)*
Sensory receptors (eye)	• *Names the parts of the eye involved in vision (iris, cornea, crystalline lens, retina)* • *Describes the functions of the main parts of the eye*
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Snell's laws (reflection) - Incident and reflected rays	• Defines a light ray as a theoretical structure indicating the direction of the propagation of light • Identifies incident rays and reflected rays in a diagram or in an actual situation • Distinguishes diffuse reflection from specular reflection in various situations
- Angle of incidence and reflection	• Measures the angles of incidence and angles of reflection in a diagram or an experiment • Explains qualitatively or quantitatively a phenomenon using the Law of Reflection (e.g. minimum height a mirror must have in order for a person to see the full length of his/her body)

Geometric optics (cont.)	
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Snell's laws (refraction)	
- Incident and refracted rays	• Identifies incident and refracted rays in a diagram or an actual situation
- Angle of incidence and refraction	• Measures the angles of incidence and the angles of refraction in a diagram or an experiment
- Index of refraction	• Defines the index of refraction of a medium as the ratio of the speed of light in a vacuum to the speed of light in that medium ($n = c/v$)
	• Determines, in experiments or mathematically, the indices of refraction of various media
	• Explains qualitatively and quantitatively a phenomenon using the Law of Refraction ($n_1 \sin\theta_1 = n_2 \sin\theta_2$) (e.g. a straw in a glass of water)
	• Explains the phenomenon of total internal reflection (e.g. mirage, fibre optics)
Images	
- Type of image (real, virtual)	• Explains the distinction between a real image and a virtual image
- Image characteristics (magnification, position)	• Describes qualitatively the characteristics of the image formed in a given situation (mirrors and lenses)
	• Applies the mathematical relationships that make it possible to determine the position, orientation and height of an object or its image in the case of mirrors or lenses ($M = h_i/h_o = -d_i/d_o$; $1/d_i + 1/d_o = 1/f$)

2. Techniques

The techniques presented here are grouped in two categories. Many of these techniques require the use of instruments and the handling of objects. Safety and the use of safety equipment must be a constant concern for all those using such techniques.

In the Laboratory	
TECHNIQUES	**KNOWLEDGE TO BE ACQUIRED**
Laboratory work	
• Safely using laboratory materials and equipment	• Uses laboratory materials and equipment safely (e.g. handles laser beam correctly to avoid receiving the ray in the eye, takes into account the high temperature of the source object and the ray box when using lasers)
• Using observational instruments	• Uses an observational instrument appropriately (e.g. screen, semi-circular basin, recording tape, digital camera)
Measurement	
• Checking the reliability, accuracy and sensitivity of measuring instruments	• Takes the same measurement several times to check the reliability of the instrument used • Carries out the required operations to ensure the accuracy of a measuring instrument (e.g. uses a lens of a known focal length, verifies whether the same focal distance value can be obtained from a setup) • Chooses a measuring instrument by taking into account the sensitivity of the instrument (e.g. uses an optical bench rather than an improvised setup to measure different positions and distances; uses a spark timer accurate to 1/32 of a second rather than a manual chronometer subject to the operator's reflexes)
• Interpreting measurement results (significant figures, measurement errors)	• Determines the margin of error attributable to a measuring instrument (e.g. the error in a measurement made using a metric ruler or protractor corresponds to half of the smallest division on the scale) • Identifies measurement errors associated with the user and the environment • Expresses a result with a number of significant figures that takes into account the errors related to the measure (e.g. a measurement between 10.3 and 10.4 cm, taken with a ruler graduated in millimetres, should be expressed as 10.35 cm or 103.5 mm) • Expresses the value of a measurement with its absolute or relative uncertainty (e.g. 24.1 ± 0.1 cm^3 or 24.1 cm^3 ± 0.4%)

B) CULTURAL REFERENCES

Cultural references make learning situations more meaningful. The following table presents some of the references related to this course. Learning situations may also draw on other cultural references.

<table>
<tr><th colspan="5">Cultural References</th></tr>
<tr><td>Technical objects, technological systems, processes and products</td><td colspan="4"><u>Kinematics</u>
- Instruments for measuring speed (e.g. radar speedometer, stroboscope, chronometer)
- Means of transportation
- Elevator
- Ballistics
- Projectiles (ballistics, ball)
- Rocket
- Computer animation

<u>Geometric optics</u>
- Mirages and optical illusions
- Rainbows
- Corrective lenses and contact lenses
- Photography
- Conjuring tricks
- Rear-view mirrors
- Observation instruments (e.g. microscope, telescope, binoculars)
- Fibre optics
- Overhead projector, cinematograph and kaleidoscope</td></tr>
<tr><th>Area</th><th>Scientists</th><th>Community Resources</th><th>Applications</th><th>Events</th></tr>
<tr><td>The Material World</td><td>Isaac Newton
Pierre Varignon
Joseph Louis Lagrange
Sofia Brahe
René Descartes
Willebrord Snell
Galileo Galilei
Louis and Auguste Lumière</td><td>Association canadienne francophone pour l’avancement de la science (ACFAS)
Canadian Space Agency (CSA)
Schools and faculties of engineering
Ministère des Transports du Québec
Observatory at Mont-Mégantic
Montréal Planetarium
Scientific and technical museums
Science clubs
Ordre des ingénieurs du Québec (OIQ)
Education kits from the Société de l’assurance automobile du Québec (available in French only):
- La mécanique prend la route
- L’optique prend la route</td><td></td><td>World fairs
Science fairs</td></tr>
</table>

FAMILIES OF LEARNING SITUATIONS

The learning situations in this course, derived from the *Research* and *Expertise* families, are related to the motion of bodies and to the deviation of light rays. The paragraphs below contain examples of tasks that the adult learner can carry out in learning situations that draw on various concepts.

Based on a situation involving the motion of a projectile projected from a launching ramp, the adult learner may be asked to determine the angle of incline of the ramp and the initial speed of the projectile (for example, a bullet) that would be necessary for the projectile to reach its target.

In a learning situation involving the refraction and formation of images, the adult learner can gain an understanding of how the crystalline lens of the human eye functions or how certain vision problems can be corrected with the help of appropriate lenses. In carrying out these tasks in the laboratory, the adult learner can determine the curvature of different lenses, construct models for the principal light rays for convergent and divergent lenses, or observe the characteristics of the images formed.

In a fictitious situation related to astronomy, the adult learner can find the speed of displacement for a meteorite observed with a powerful telescope in order to determine the exact time it will hit the Earth and at what location. The learner must take into account the enlargement of the telescope and the deceleration of the meteorite after it enters the Earth's atmosphere, as well as the effect of gravitational acceleration.

In the learning situation described on the following page, the main tasks help adult learners develop the first and third competencies. This situation therefore belongs to the *Research* family.

BROAD AREAS OF LEARNING

Learning situations are more meaningful for adult learners when their context is connected to the broad areas of learning. The broad areas of learning most readily applicable to the learning situations for the course PHS-5061-2 are *Health and Well-Being*, *Career Planning and Entrepreneurship* and *Environmental Awareness and Consumer Rights and Responsibilities.* The following example reflects the educational aim of the broad area of learning *Health and Well-Being*.

Broad Areas of Learning
Health and Well-Being
Career Planning and Entrepreneurship
Environmental Awareness and Consumer Rights and Responsibilities
Media Literacy
Citizenship and Community Life

EXAMPLE OF A LEARNING SITUATION

CHECK YOUR BLIND SPOTS

A friend who has taken a driving course confides to you how stressed he is. His instructor has explained the principle of a blind spot when changing lanes but he does not really understand it. When you get into the car he is driving, you realize that his mirrors are badly positioned. You must explain to him the principle of the blind spot, using the phenomenon of reflection. Your task consists of listing all the car's mirrors and their characteristics, and then of optimizing their positions in order to minimize the blind spots. You must demonstrate the effectiveness of the optimal positions using the concept of field of vision and a diagram of the situation, drawn to scale. Finally, you will explain to him how to estimate the time available to him to change lanes with respect to an approaching car that he can see in the field of vision of the left mirror.

You will be required to design a protocol to test the fields of vision in plane and curved mirrors. Using your friend's car, you will determine the optimal positions for the mirrors and evaluate the distance that a car coming from the left lane must cover between the time it appears in the field of vision of the left mirror and the time it arrives directly beside your car. You will then write up a laboratory report on the question. In this way, you will be prepared to draw a scale diagram of the car equipped with mirrors and in which a passenger is sitting. You will clearly determine the driver's field of vision as well as the blind spots that you can identify. You will then determine how much time is available to you according to the relative speed of the cars before the car catches up to you. Finally, you must make recommendations to your friend concerning the position of the mirrors and the estimated time available to pass a vehicle, backed up by scientific proof.

Expected outcome:

- list of mirrors present in/on the car and their characteristics
- laboratory report on the fields of vision of a car's mirrors
- diagram to scale of the situation with the position of the mirrors optimized
- calculations of distances and times available to pass a vehicle, based on the relative speed of the vehicles
- explanation of the results of optimizing the different mirrors
- recommendation as to how to estimate the time available to pass a vehicle

END-OF-COURSE OUTCOMES

Learning situations are administered on the premise that the adult learner will become familiar with an investigative involving the experimental method, the observation method or modelling. In physics, these learning situations foster the implementation of problem-solving skills, the use of knowledge and the production of messages.

Adult learners who solve a problem related to the motion of a body or the deviation of the trajectory of light form a representation of the problem based on their reading and interpretation of scientific and technological messages. They develop a plan of action for one of their hypotheses, making use of their knowledge of kinematics or optics. They are guided in writing up an experiment protocol and determining constant parameters and independent and dependent variables. They implement a plan of action by carrying out activities in the laboratory; they gather data taking into account the experimental uncertainty related to the precision of the measuring instruments used; and they apply the appropriate safety rules. Using an outline, they process data, analyze results and write up discussions about the experiment and its conclusion. If applicable, their report mentions the sources of errors that may explain the discrepancy between their results and those predicted by the theory.

Adult learners who study a phenomenon or technical application of kinematics or optics formulate questions on the contextual aspects and identify the physics principles involved. Using diagrams, concepts, laws, theories or models, they explain the role of kinematics or optics in the description of certain phenomena or in the operation of an application. In this way, they calculate the position, speed and acceleration of a body or the range and maximum height of a projectile using equations of motion. They illustrate the formation of an image with a mirror or a lens using the traces of principal light rays. They determine the position and characteristics of an image using the relationships between similar triangles. Finally, the adult learners demonstrate their understanding of physics principles by describing the effect of the variation of certain initial parameters, and by applying their explanations to other phenomena or applications governed by the same principles.

EVALUATION CRITERIA FOR THE COMPETENCIES TARGETED BY THE COURSE

Evaluation Criteria for Competency 1	Evaluation Criteria for Competency 2	Evaluation Criteria for Competency 3
▪ Appropriate representation of the situation ▪ Development of a suitable plan of action ▪ Appropriate implementation of the plan of action ▪ Development of relevant explanations, solutions or conclusions	▪ Formulation of appropriate questions ▪ Appropriate use of knowledge of physics ▪ Suitable production of explanations	▪ Accurate interpretation of scientific or technological messages ▪ Appropriate production or transmission of scientific or technological messages

Course

PHS-5062-2

Dynamics and Transformation of Mechanical Energy

Physics

INTRODUCTION

The course entitled *Dynamics and the Transformation of Mechanical Energy* is aimed at enabling adult learners to function effectively in situations from the *Research* and *Expertise* families which concern the application of forces to a body and the concept of work or mechanical energy.

The adult learners enrolled in this course study phenomena or technical applications related to the concepts of dynamics and the transformation of energy, and look for solutions to problems related to this area of physics. They must therefore acquire knowledge about the concepts of work and force, which do not mean the same thing in physics as they do in common usage. They deepen their knowledge of different types of forces and the principle of the conservation of energy that they studied in Secondary IV. This knowledge enables them to explain the factors that underlie certain phenomena, such as the emission of heat in a braking system or the point when a parachute reaches a constant falling speed. It can also enable them to understand the operation of technological applications such a bathroom scale or the shock absorbers of a car. In addition, since experimentation and modelling occupy a central role in the development of competencies and the construction of knowledge related to the concepts in the course, adult learners carry out several laboratory activities designed to help them autonomously exercise the particular skills related to techniques and methods.

By the end of this course, in *Research* and *Expertise* situations, adult learners will be able to:

- ✓ carry out an investigative process that includes experimentation to solve a problem related to the application of multiple forces on a body and how this affects the energy involved
- ✓ analyze a phenomenon or technological application related to the concepts of forces and mechanical energy
- ✓ use Newton’s laws to predict the effects of applying forces to a body
- ✓ verify the principle of the conservation of mechanical energy in a phenomenon or application
- ✓ follow an experimental protocol that they have prepared; one which deals with the effect of one or more forces on a body, with or without consideration of the mechanical energy involved
- ✓ write a laboratory report on the effect of one or more forces on a body, with or without consideration of the mechanical energy involved

SUBJECT-SPECIFIC COMPETENCIES

The following table lists, for each competency, the key features studied in the course. The manifestations of the key features are presented in Appendix 4.

Competency 1 Seeks answers or solutions to problems involving physics	Competency 2 Makes the most of his/her knowledge of physics	Competency 3 Communicates ideas relating to questions involving physics, using the languages associated with science and technology
▪ Defines a problem ▪ Develops a plan of action ▪ Carries out the plan of action ▪ Analyzes his/her results	▪ Identifies the principles of physics underlying a phenomenon or application ▪ Analyzes the principles of physics underlying a phenomenon or application ▪ Explains a phenomenon or an application from the standpoint of physics	▪ Interprets scientific or technological messages ▪ Produces scientific or technological messages

PROCESSES

The investigative processes enable adult learners to solve problems involving the principles of physics and to study an application or phenomenon connected with the transformation of energy or the application of forces to a body. The following are the steps in the investigative process:

- Define the problem
- Formulate a hypothesis
- Test the hypothesis
- Draw conclusions and communicate

The most appropriate investigative processes for this course are: the observation method, the experimental method and modelling. It is during the step of verifying a hypothesis that these methods become distinguishable. Section 3.5 and Appendixes 1 to 3 present these investigative processes, with their respective characteristics.

In this course, laboratory experiments require adult learners to carry out specific tasks in accordance with the following limitations and instructions.

Experimental Method	
Steps	**Tasks**
1. Plans an experiment	The adult learner: – writes up an experimental protocol for physics – selects the materials required to do an experiment – identifies the applicable safety rules, the constant parameters and the parameters to be investigated (independent variable, dependent variable)
2. Conducts the experiment	The adult learner: – follows the experimental protocol and adjusts it as required – takes measurements, keeping in mind the factor of experimental error – applies the appropriate safety rules
3. Interprets the results	In writing up a report, the adult learner: – takes significant figures into account when processing the data – analyzes the results – estimates the maximum allowable error due to the user and the environment – discusses the results – writes the conclusion, making connections with the problem in question

CROSS-CURRICULAR COMPETENCIES

The cross-curricular competencies supplement the subject-specific competencies. The development of one contributes to the development of the others. Course PHS-5062-2 allows for putting all the cross-curricular competencies into practice. Some of them, indicated in grey shading in the table below, are especially targeted in the sample learning situation presented for the requirements of the course.

Cross-Curricular Competencies			
Intellectual	**Communication-Related**	**Personal and Social**	**Methodological**
Uses information	Communicates appropriately	Achieves his/her potential	Adopts effective work methods
Solves problems		Cooperates with others	Uses information and communications technologies
Exercises critical judgment			
Uses creativity			

SUBJECT-SPECIFIC CONTENT

A) KNOWLEDGE

The compulsory concepts and techniques are presented in the tables in the following two sections.

1. Concepts

The knowledge written in italics has been acquired in the science and technology programs and must be mobilized again in this course.

The Material World	
General concept: Dynamics Dynamics studies the causes of changes in motion. 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. For a body in free fall, special attention is paid to gravitational force, which leads to the study of the concept of gravitational acceleration.	
COMPULSORY CONCEPTS	**PREVIOUSLY ACQUIRED KNOWLEDGE**
Adhesion and friction of parts	• *Describes the advantages and disadvantages of the adhesion and friction of parts in a technical object*
Constraints	• *Describes the constraints to which different technical objects are subject: tension, compression, torsion, deflection, shearing (e.g. a diving board is subject to deflection)*
Pressure	• *Defines pressure as the force exerted by particles when they collide with a constricting surface*
Relationship between mass and weight	• *Describes qualitatively the relationship between mass and weight* • *Applies the mathematical relationship between mass and weight* ($F_g = mg$)
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Newton's laws	• Describes qualitatively the law of inertia (Newton's First Law) • Describes qualitatively the relationship between the force acting on a body, its mass and its acceleration (Newton's Second Law) • Applies the mathematical relationship between the force acting on a body, mass and acceleration *(F = ma)* • Describes qualitatively the law of action-reaction (Newton's Third Law) • Explains a phenomenon or how a technical object works, using Newton's laws
Centripetal force	• Explains qualitatively the effect of centripetal force on a body in motion
Free-body diagram	• Uses vectors to represent the forces that act on a body
Equilibrium and resultant of several forces	• Determines the magnitude and direction of the vector associated with the resultant force of a system of forces • Determines the magnitude and direction of the vector associated with the balancing force of a system of forces

Dynamics (cont.)	
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Force of friction	• Explains the possible effects of a frictional force (slows down, stops or impedes the motion of a body) • Names the factors that can affect the force of friction in a given situation (e.g. nature of the surfaces that are in contact, shape of a body that is moving in a fluid) • Determines the value of the force of friction in a given situation (force of friction = applied force - net force)
Gravitational acceleration	• Compares the average values of gravitational acceleration on Earth and on the moon (9.8 m/s^2 on the Earth, 1.6 m/s^2 on the moon)
Gravitational force	• Associates the free fall of a body with the effect of gravitational force • Associates the gravitational force of a body with its weight • Determines the component of gravitational force parallel to the displacement of a body (e.g. inclined plane)
Hooke's law	• Describes qualitatively the relationship between the force applied to a helical spring and the variation in its length • Applies the mathematical relationship between the force applied, the spring constant and the extension of a helical spring *(F=kx)*
Effective force	• Defines effective force as the component of the applied force parallel to the direction of travel • Determines graphically the magnitude of the effective force in a given situation

General concept: Transformation of energy

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. 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.

Note: *Hooke's law is studied only in connection with helical springs.*

COMPULSORY CONCEPTS	**PREVIOUSLY ACQUIRED KNOWLEDGE**
Forms of energy	• *Describes different forms of energy (chemical, thermal, mechanical, radiation)* • *Defines joule as the unit of measurement for energy*
Law of conservation of energy	• *Explains qualitatively the law of conservation of energy* • *Applies the law of conservation of energy in different contexts*
Energy efficiency	• *Defines the energy efficiency of a device or system as the proportion of energy consumed that is transformed into effective work (amount of useful energy / amount of energy consumed x 100)*
Relationship between power and electrical energy	• *Describes qualitatively the relationship between the power of an electrical appliance, the electrical energy it consumes and the amount of time it is in operation* • *Applies the mathematical relationship between electrical energy consumed, the power of an electrical appliance and the amount of time it is in operation ($E = P\Delta t$)*

COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Mechanical energy	• Explains qualitatively a transformation of mechanical energy in a given situation (e.g. a merry-go-round in motion) • Applies the mathematical relationships associated with kinetic energy, types of potential energy (gravitational, elastic), work and heat • Analyzes quantitatively a transformation of mechanical energy in a given situation
Relationship between work, force and distance travelled	• Describes qualitatively the relationship between the work done, the force applied on a body and the distance travelled by the body • Applies the mathematical relationship between work, effective force and distance travelled *(W = F⊿d)*
Relationship between energy, the spring constant and the change in length of a helical spring	• Explains qualitatively the relationship between the energy of a helical spring, its spring constant and the change in its length in a given situation (e.g. the springs in a mattress) • Applies the mathematical relationship between elastic potential energy, the spring constant and the change in length in a given situation ($E = ½ kx^2$)
Relationship between power, work and time	• Explains qualitatively the relationship between the power of a system, the work done and the time taken to do the work (e.g. a racing car) • Applies the mathematical relationship between power, work and time ($P = W/\Delta t$)

Transformation of energy (cont.)

COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Relationship between work and energy	• Describes qualitatively the relationship between the work done on a body and the variation in energy within that body • Applies the mathematical relationship between work and energy ($W = \Delta E$)
Relationship between potential energy, mass, gravitational acceleration and distance travelled	• Describes qualitatively the relationship between the potential energy of a body, its mass, its gravitational acceleration and the distance it travels • Applies the mathematical relationship between potential energy, mass, gravitational acceleration and the distance travelled ($Ep = mgh$)
Relationship between kinetic energy, mass and speed	• Describes qualitatively the relationship between the kinetic energy of a body, its mass and its speed • Applies the mathematical relationship between kinetic energy, mass and speed ($E_k = ½ mv^2$)

2. Techniques

The techniques presented here are grouped in two categories. Many of these techniques require the use of instruments and the handling of objects. Safety and the use of safety equipment must be a constant concern for all those using such techniques.

In the Laboratory	
TECHNIQUES	**KNOWLEDGE TO BE ACQUIRED**
Laboratory work	
• Safely using laboratory materials and equipment	• Uses laboratory materials and equipment safely (e.g. makes sure the way is clear when experimenting with masses, protects the ground when studying free fall)
• Using observational instruments	• Uses an observational instrument appropriately (e.g. force table, digital camera)
Measurement	
• Checking the reliability, accuracy and sensitivity of measuring instruments	• Takes the same measurement several times to check the reliability of the instrument used • Carries out the required operations to ensure the accuracy of a measuring instrument (e.g. calibration of a dynamometer) • Chooses a measuring instrument by taking into account the sensitivity of the instrument (e.g. uses a spark timer accurate to 1/15 of a second rather than a manual chronometer subject to the operator's reflexes; chooses a dynamometer in accordance with the forces to be measured)
• Interpreting measurement results (significant figures, measurement errors)	• Determines the margin of error attributable to a measuring instrument (e.g. the error attributable to a digital chronometer corresponds to the smallest division; the error attributable to a metric ruler corresponds to half of the smallest division on the scale) • Estimates measurement errors associated with the user and the environment • Expresses a result with a number of significant figures that takes into account the errors related to the measure (e.g. a measurement between 10.3 and 10.4 cm, taken with a ruler graduated in millimetres, should be expressed as 10.35 cm or 103.5 mm) • Expresses the value of a measurement with its absolute or relative uncertainty (e.g. $24.1 \pm 0.1\ cm^3$ or $24.1\ cm^3 \pm 0.4\%$)

B) CULTURAL REFERENCES

Cultural references make learning situations more meaningful. The following table presents some of the references related to this course. Learning situations may also draw on other cultural references.

<table>
<tr><th colspan="5">Cultural References</th></tr>
<tr><td>Technical objects, technological systems, processes and products</td><td colspan="4"><u>Dynamics and transformation of mechanical energy</u>
- Road signs
- Elevators
- Rockets
- Parachuting
- Bungee jumping
- Elements of aerodynamics (e.g. car fins, aircraft wings)
- Balances and bathroom scales
- Safety equipment for sports and work (helmets, hard hats, various protectors)
- Fitness equipment
- Propellers (e.g. boat, wind turbines, airplanes)
- Tectonic plates
- Weightlessness
- Geostationary satellites
- Civil engineering structures (e.g. bridges, towers, buildings, dams, roads)
- Automobile systems (e.g. ABS brakes, shock absorbers)
- Roller coasters and merry-go-rounds
- Pendulum clocks
- Slings
- Means of transportation (e.g. automobiles, airplanes, boats, trains)
- Turbines (e.g. electricity plants, jets)
- Simulators</td></tr>
<tr><th>Area</th><th>Scientists</th><th>Community Resources</th><th>Applications</th><th>Events</th></tr>
<tr><td>The Material World</td><td>Isaac Newton
Archimedes
Robert Hooke
James Joule
James Watt
Johannes Kepler</td><td>Association canadienne francophone pour l’avancement de la science (ACFAS)
Canadian Space Agency (CSA)
Schools and faculties of engineering
Ministère des Transports du Québec
Montréal Planetarium
Scientific and technical museums
Science clubs
Ordre des ingénieurs du Québec (OIQ)
Education kit from the Société de l’assurance automobile du Québec (available in French only): La mécanique prend la route</td><td></td><td>World fairs
Science fairs
Nobel prize in Physics
Engineering challenges</td></tr>
</table>

FAMILIES OF LEARNING SITUATIONS

The learning situations in this course, derived from the *Research* and *Expertise* families, are related to the effects of applying one or more forces to a body and to questions of mechanical energy. The paragraphs below contain examples of tasks that the adult learner may be asked to carry out.

Based on a situation involving the balance of forces and centripetal force, adult learners may be asked to explain, using a free body diagram, why a passenger feels “pushed” towards the outside when a car goes into a curve, or why the turns in a road are constructed with an incline.

A situation designed to study the transformation of elastic potential energy into kinetic or gravitational potential energy might require the adult learners to determine experimentally the force constant of a spring. They would then be able to evaluate the total quantity of energy initially held by an object in order to predict the maximum height or speed that can be attained by a projectile launched by a spring system.

Dynamics and the transformation of energy can also be studied in a learning situation involving the path of a miniature car on a track that has elevations and descents. In this situation, focusing on the concepts of friction and work might prompt the adult learners to experimentally measure the work required to move the car in a friction situation. They can then evaluate the effect of this friction on losses of energy.

In the learning situation described on the following page, the main tasks help adult learners develop the second and third competencies. This situation therefore belongs to the *Expertise* family.

BROAD AREAS OF LEARNING

Learning situations are more meaningful for adult learners when their context is connected to the broad areas of learning. The broad areas of learning most readily applicable to the learning situations for the course PHS-5062-2 are *Health and Well-Being*, *Career Planning and Entrepreneurship*, *Environmental Awareness and Consumer Rights and Responsibilities* and *Citizenship and Community Life.* The following example reflects the educational aim of the broad areas of learning *Health and Well-Being* and *Citizenship and Community Life.*

Broad Areas of Learning
Health and Well-Being
Career Planning and Entrepreneurship
Environmental Awareness and Consumer Rights and Responsibilities
Media Literacy
Citizenship and Community Life

EXAMPLE OF A LEARNING SITUATION

A ROAD BUILT TO MEASURE

In the theory section of a driving course, you have learned that a road sign placed at the entrance to a bend in a road will post the maximum speed permitted for drivers negotiating the curve. Also, you have noticed that on a road under construction near your house, there is a very tight curve and the maximum speed sign has not been put up yet. Before the Ministère des Transports installs the sign, you want to test your competencies and predict what the maximum speed should be for this bend in the road.

Your task consists in recommending a maximum speed for taking the curve, based on the principles of physics. You must first list the forces that are exerted on a vehicle when it is in a turn. Then, you will be required to determine the parameters that affect the force of friction between the tires of the vehicle and the road surface, and the relationships that connect them. After processing this information, you will be able to predict the maximum speed that will be posted. Furthermore, based on realistic friction coefficients, you will be able to determine the maximum speeds for driving in a curve when the pavement is wet and when it is dry. In addition, you will be able to evaluate how changing the incline of the road will influence the maximum allowable speed.

Expected production:

- a list and a representation, using a free body diagram, of the forces that are exerted on a vehicle in motion in a curve
- a report presenting the parameters that affect the friction between the tires and the road surface, the processing of this information and your prediction
- a comparative study of the influence of the different parameters (incline, state of the road surface, bending radius) on the maximum speed posted

END-OF-COURSE OUTCOMES

Learning situations are administered on the premise that the adult learner will become familiar with an investigative involving the experimental method, the observation method or modelling. In physics, these learning situations foster the implementation of problem-solving skills, the use of knowledge and the production of messages.

Adult learners solving a problem related to dynamics or the transformation of mechanical energy form a representation of the problem based on their reading and interpretation of scientific and technological messages. They must also develop a plan of action for one of their hypotheses, making use of their knowledge of forces, work and mechanical energy. In order to do this, the adult learners must write up an experiment protocol in which they select the required material, establish the instructions for handling the materials and determine the applicable safety rules. They must also implement a plan of action by carrying out the prescribed activities in the laboratory. During these

activities, they handle the materials correctly, apply the appropriate safety rules and take measurements, taking into account the uncertainty associated with the instruments used and the experimental conditions. In a laboratory report, they present a rigorous analysis of the results and discuss them. Lastly, they write up the conclusions of the experiment, making connections with the initial problem. Their report mentions the sources of errors and their estimated values.

Adult learners who study a phenomenon or technical application related to the forces that act on a body or to the concept of mechanical energy formulate questions on the contextual aspects and identify the physics principles involved. Using diagrams, concepts, laws, theories or models, they explain the role of forces present, the work accomplished, the transmission of power or the transformations of mechanical energy. They illustrate the application of several forces on a body by means of a free body diagram; they predict quantitatively the speed of a body in free fall in relation to its height by means of the principle of conservation of mechanical energy; they explain the relationship between the motion of a body, the work accomplished, mechanical energy and its conservation; and they explain Hooke's law by making a connection between the deformation of a spring and the spring constant associated with it. Finally, the adult learners demonstrate their understanding of the principles of physics by describing the effect of the variation of certain initial parameters, and by applying their explanations to other phenomena or applications governed by the same principles.

EVALUATION CRITERIA FOR THE COMPETENCIES TARGETED BY THE COURSE

Evaluation Criteria for Competency 1	Evaluation Criteria for Competency 2	Evaluation Criteria for Competency 3
▪ Appropriate representation of the situation ▪ Development of a suitable plan of action ▪ Appropriate implementation of the plan of action ▪ Development of relevant explanations, solutions or conclusions	▪ Formulation of appropriate questions ▪ Appropriate use of knowledge of physics ▪ Suitable production of explanations	▪ Accurate interpretation of scientific or technological messages ▪ Appropriate production or transmission of scientific or technological messages

Appendixes

Appendix 1

Exploration and analytical strategies enable the adult learner to progress more effectively towards an answer or solution when using an investigative process.

Exploration Strategies

- Collecting as much scientific, technological and contextual information as possible to define a problem or predict patterns
- Referring to similar problems that have already been solved
- Anticipating the results of a process
- Developing various scenarios
- Exploring various possible solutions
- Considering various points of view on scientific issues

Analytical Strategies

- Determining the constraints and important elements involved in solving a problem
- Dividing a complex problem into simpler subproblems
- Using different types of reasoning (e.g. inference, inductive and deductive reasoning, comparison, classification, prioritization) in order to process information
- Reasoning by analogy in order to process information and adapt scientific and technological knowledge
- Generalizing from particular cases that are structurally similar
- Selecting relevant criteria that help determine where one stands on a scientific issue

Appendix 2

Investigative Processes	
Steps	**Examples**
Define the problem	Identify the relevant information. Find the related concepts. Use personal theoretical knowledge, theoretical knowledge drawn from documents, previous experiments, past experience or logic.
Formulate a hypothesis	Develop questions based on different facts. Make analogies or try to predict results. Establish causal relationships. Propose a model.
Test the hypothesis	Prepare and make observations, conduct an experiment or build a model to prove or disprove the initial hypothesis.
Draw conclusions	Express understanding of the facts. Produce an explanation or a new model or theory.
Communicate	Formulate an answer, solution, explanation, model or opinion.

Appendix 3

Scientific methods for testing a hypothesis

Modelling	
Modelling consists in constructing a concrete representation of an abstract situation that is difficult to observe or impossible to see. A model must help people understand a given reality, explain certain properties of what it attempts to represent, and help people predict new phenomena. The model can take different forms: a text, a drawing, a mathematical or chemical formula or equation, a software program or a scale model.	
Steps	**Examples**
1. Develop a model	- Identify the components and the relationships between them - Choose the method of representation
2. Build the model	- Make a scale model or a diagram - Develop a formula
3. Validate the model	- Identify possible contradictions and inconsistencies - Verify the validity of the elements - Make changes or go back to the preceding steps, if necessary

Observation Method	
The scientific observation method helps observers to interpret facts on the basis of predetermined criteria and generally accepted elements within a given field. In light of the information collected, observers gain a new understanding of the facts, which is inextricably linked to the context in which the observations were made. Based on the way they interpret and organize information, the observers reinterpret the world, taking into consideration their prior knowledge and the conceptual schemes that they apply to the facts observed.	
Steps	**Examples**
1. Plan the observation	- Determine the observation criteria - Prepare an observation checklist
2. Gather information	- Gather information, referring to the observation criteria
3. Interpret the information	- Organize the information in order to explain the phenomenon or the application - Make connections between the items of information gathered

Experimental Method	
The experimental method involves the development of an experimental procedure that includes the identification of a certain number of variables. 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 allows adult learners to ask bold questions, to formulate new hypotheses, to adjust the experimental procedure and to take the limitations of the experiment into account.	
Steps	**Examples**
1. Plan an experiment	- Determine the possible variables - Determine the variable to be measured - Break the experiment down into steps
2. Conduct the experiment	- Prepare an apparatus for the experiment - Perform a set of tasks - Make observations or take measurements
3. Interpret the results	- Process the data collected - Establish relationships - Discuss possible errors

Appendix 4

Competency 1 Seeks answers or solutions to problems involving physics	Competency 2 Makes the most of his/her knowledge of physics	Competency 3 Communicates ideas relating to questions involving physics, using the languages associated with science and technology
Defines a problem • Determines the elements that seem relevant • Determines the relationships between the different elements • Reformulates the problem in terms of physics concepts • Formulates realistic hypotheses or possible solutions **Develops a plan of action** • Chooses a hypothesis or a solution • Determines the necessary resources • Plans the steps involved in implementing the plan of action **Carries out the plan of action** • Handles equipment and substances and carries out planned operations • Gathers potentially useful data or observations • Adjusts the plan of action or its implementation, if necessary **Analyzes his/her results** • Processes the data gathered or his/her observations • Looks for significant patterns or relationships • Makes connections between his/her results and physics concepts • Judges the appropriateness of the answer or solution found • Formulates new hypotheses or solutions, if applicable	**Identifies the principles of physics underlying a phenomenon or application** • Considers the elements of the context • Identifies the principles of physics • Creates a representation of the phenomenon or application, based on physics concepts **Analyzes the principles of physics underlying a phenomenon or application** • Describes the principles of physics underlying a phenomenon or application qualitatively or quantitatively • Uses concepts, laws, theories or models to establish the relationships between physics principles underlying a phenomenon or application **Explains a phenomenon or an application from the standpoint of physics** • Develops an explanation based on scientific concepts, laws and models of physics • Justifies his/her explanation using scientific and, if necessary, mathematical formalism • Adapts the proposed explanation to other contexts, if applicable	**Interprets scientific or technological messages** • Places the message in context • Makes sure the sources are reliable • Selects the elements needed to interpret the message • Grasps the precise meaning of words or statements • Establishes connections between concepts and their graphic or symbolic representations **Produces scientific or technological messages** • Structures his/her message • Uses scientific and technological vocabulary • Uses the symbolic and graphical languages associated with science and technology • Adheres to the established standards and conventions for the different languages • Demonstrates rigour and coherence • Respects intellectual property rights

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