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PHYSICS PROGRAM
SECONDARY V

FEBRUARY 2000

Québec

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Direction de la formation générale des adultes
Service de l'évaluation des apprentissages

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In accordance with section 461 of the *Education Act* (R.S.Q., c. 1-13.3), I approve the new Secondary V program of study, *Physics,* as an optional subject in adult education.

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Minister of Education

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INTRODUCTION

1. Background

The Secondary V *Physics* program is intended for secondary-level adult education students in Québec. It comprises three 50-hour courses, equivalent to the *Physics 534* program offered in the youth sector.

According to the basic school regulation, this program is optional in the second cycle of secondary school and, as such, credits awarded for the three courses may be applied toward obtaining a *Secondary School Diploma* (SSD). Also, the three courses are equivalent to the *Physics 534* program, which is a prerequisite for admission to certain general and technical education programs at the college level.

1.1 Context in which the program was developed

In 1991, following the review of adult education science programs, the Direction générale de l'éducation des adultes set up an advisory committee whose mandate was to analyze the content of the new Secondary V chemistry and physics programs in the youth sector with a view to their implementation in the adult sector.

The committee determined that, although the content of the youth-sector programs was entirely relevant, these programs could not be implemented without changes because of certain organizational and andragogical constraints in adult education. It therefore recommended that the programs be rewritten in order to adapt the objectives and approach to the adult sector. In order to harmonize the programs in the two sectors, it was agreed that the content of the youth-sector program would be retained and that particular attention would be paid to the development of skills related to the experimental method.

In the winter of 1994, work on the new adult-sector physics program began. A first version was submitted to the school boards for consultation in April 1996. Teachers and non-teaching professionals from more than forty school boards participated in the project. This version of the program reflects their comments.

1.2 Relationship to other programs

1.2.1 Youth-sector programs

The related content of the Secondary V *Physics* program has been harmonized with that of the *Physics 534* program in the youth sector. The content of the youth-sector program has been divided into three courses: *Optics; Kinematics and Momentum;* and *Forces and Energy.* Furthermore, elements of the youth-sector program*, The Tools and Methods of Science* (TMS 532), have been integrated into each course of the program.

1.2.2 Adult-sector programs

This program replaces the previous program, in particular the courses *Physics 243, Physics 251* and *Physics 252.*

1.2.3 Prerequisites

The three courses in the adult education Secondary IV *Physical Sciences* program or *Physical Sciences 436* in the youth sector or their equivalent are prerequisites to the Secondary V *Physics* program.

In addition, since this is a Secondary V program, students must have successfully completed the Secondary IV language of instruction and mathematics courses.

1.3 Development of skills related to the experimental method

The need to emphasize experimentation as a means of integrating knowledge and as an integral part of the curriculum leading to postsecondary education in the sciences led to the development of a Secondary V physics program that focuses largely on the experimental method and the development of related skills. These skills should be evaluated in the same capacity as related content at the end of the courses.

Because of the particular nature of adult education and its organizational constraints, students are introduced to the experimental method in the Secondary V science courses. Such an introduction, however, requires more time than is available in the 50-hour duration of a course. That is why the skills required to perform the experimental method are introduced step by step as the student moves through the three courses. While terminal objectives have been set for each course, the level of competency targeted by the program can be attained only after all three courses have been successfully completed.

The first course familiarizes students with the elements of experimental procedure, with laboratory work and with the presentation and analysis of experimental data.

The second course builds on this knowledge. Students will be called upon to write up an experimental procedure, follow an experimental procedure and write the different parts of a laboratory report.

The third course focuses on integration. At the end of this course, the students should be able to write an experimental procedure, carry out the related experiments and write the laboratory report.

While strictly adhering to the learning objectives related to the experimental method, the authors have attempted to be realistic with respect to the means available to adult education centres and to the specific nature of individualized learning. Although the development of skills related to the experimental method is absolutely essential, such development can be arrived at through relatively simple methods and in a manner accessible to the greatest number of centres possible.

1.4 The HTS (history-technology-society) perspective

As a follow-up to the Secondary IV *Physical Sciences* program, this physics program is designed to help students establish relationships between the theoretical concepts presented and the context in which these concepts were discovered, the influence that science and technology have had on each other throughout the years and the consequences that scientific discoveries and technological applications have had for society and the environment. This is what the authors have called the HTS perspective.

In the Secondary IV *Physical Sciences* program, this orientation was adopted for the formulation of objectives and as the approach for learning science. In this physics program, the objectives related to the HTS perspective complement the other objectives, reflecting the fact that science does not operate in a vacuum and, while it contributes to the development of society, its progress is affected by the political, social and technological realities of the time.

Each of the three courses has a terminal objective for each section: history, technology, and society and the environment.

2. Structure of the program and learning content

2.1 Relationship between the courses

The program comprises three courses, which must be studied consecutively. This sequence is necessary both because of the logical relationships between the elements of content and because of the progressive acquisition of skills related to the experimental method.

2.1.1 Course 1: Optics

In this course, by learning about the scientific method, students will gain a better understanding of optics, as well as of technical phenomena and social changes associated with the development of optics..

This course covers:

- the propagation of light;
- the behaviour of light reflected from plane and curved mirrors;
- the behaviour of light refracted by lenses and other substances;
- the electromagnetic spectrum and applications of its various ranges.

2.1.2 Course 2: Kinematics and Momentum

In this course, by learning about the scientific method, students will gain a better understanding of kinematics and momentum, as well as of technical phenomena and social changes associated with the development of mechanics.

This course covers:

- the perception of motion and the concept of trajectory;
- analysis of the trajectories of different moving objects;
- analysis of rectilinear motion and rectilinear motion with uniform acceleration;
- analysis of the two-dimensional motion of a projectile;
- applications of the principle of conservation of momentum.

2.1.3 Course 3: Forces and Energy

In this course, by learning about the scientific method, students will gain a better understanding of dynamics, as well as of technical phenomena, environmental consequences and social changes associated with the development of dynamics.

This course covers:

- the concept of force and the consequences of applying force to an object;
- gravitational force and its characteristics;
- the motion of an object as a function of work, energy and the conservation of energy;
- friction between two surfaces and air resistance on objects in motion;
- Archimedes' principle;
- the extension of a spring and pressure;
- the operation of simple and compound machines.

2.2 Learning objectives

Each course is described by a general objective and a series of terminal and intermediate objectives. A table at the beginning of each course sets out the general and terminal objectives.

2.2.1 General objectives

The general objective is a statement of the intention of the course. It specifies the relationships to be established among the three categories of terminal objectives.

2.2.2 Terminal objectives

The terminal objectives have been divided into three categories: related content, the experimental method and the HTS (history-technology-society) perspective. The order in which these objectives are presented in no way indicates their relative importance or a fixed learning sequence.

All of the terminal objectives are prescriptive. They are formulated as learning objectives.

The terminal objectives indicate the significance to be given to the learning and the target to be attained through the intermediate objectives, which describe more precisely the scope of the terminal objectives.

As a reminder of the continuity between the terminal objectives related to the experimental method, the objectives are numbered as follows: A1, A2, A3, A4 in the first course, B1, B2, B3, B4, B5 in the second course and C1, C2, C3, C4 in the third course. Objectives with the same number, for example, A1, B1 and C1, generally deal with the same aspect of the experimental method.

2.2.3 Intermediate objectives

All of the terminal objectives associated with related content are accompanied by a list of intermediate objectives. Some of these intermediate objectives are also related to a terminal objective associated with the experimental method or the HTS perspective. In such cases the letters EX (experimental method), H (history), T (technology) or S (society) appear to the left of the objective.

In addition to being related to certain intermediate objectives associated with related content (identified by the letters EX), the terminal objectives associated with the experimental method are accompanied by their own intermediate objectives. The relationships between these two categories of intermediate objectives and the terminal objectives associated with the experimental method are presented at the end of each course after the description of each terminal objective associated with related content.

None of the terminal objectives associated with the HTS perspective are accompanied by their own intermediate objectives. They are all described by intermediate objectives associated with related content. They are identified by the letter H, T or S to the left of the objective. A complete list of these objectives can be found at the end of each course.

All the intermediate objectives are prescriptive.

2.2.4 Additional information

Additional information is provided for most of the intermediate objectives associated with related content. This information is not prescriptive, limiting, or exhaustive. It is intended to help the eventual users of the program and includes details on content, limits, possible paths of exploration, and so on.

3. Evaluation of learning

The evaluation of learning aims, on the one hand, at helping students learn and, on the other, at providing the data necessary for the certification of studies. In general, information on the evaluation of learning and the certification of studies can be found in other official documents, such as the definition of the domain and the *Administrative Manual for the Certification of Studies in General Education for Adults and in Vocational Education*. Refer to these documents for further information on evaluation and certification.

Formative evaluation is a part of teaching and learning. Its purpose is to support and guide decisions concerning the choice of learning situations, instructional material and the type of pedagogical intervention. It is the responsibility of teachers and is governed by policies established by the school boards. If necessary, the Ministère may suggest conceptual frameworks or examples of formative evaluation instruments.

For purposes of summative evaluation, the Ministère provides a *Definition of the Domain* for each course in a program and, if applicable, uniform or complementary examinations. Following summative evaluation, a judgment is made on the student's attainment of the learning objectives of a course, after which learning may be certified.

CONTENT OF THE PROGRAM — COURSE BY COURSE

COURSE 1

OPTICS

By learning about the scientific method, students will gain a better understanding of optics, and of technical phenomena and social changes associated with the development of optics.

GENERAL OBJECTIVE

By learning about the scientific method, students will gain a better understanding of optics, as well as of technical phenomena and social changes associated with the development of optics.

TERMINAL OBJECTIVES

Related Content

1 To analyze the propagation of light.

2 To analyze the behaviour of light reflected from plane mirrors.

3 To analyze the behaviour of light reflected from curved mirrors.

4 To analyze the behaviour of light refracted by different substances.

5 To analyze the behaviour of light travelling through lenses.

6 To describe the electromagnetic spectrum and the applications of its various ranges.

EX Experimental Method

A1 To become familiar with the scientific method.

A2 To become familiar with the technique for writing up an experimental procedure.

A3 To become familiar with the technique for carrying out an experiment.

A4 To become familiar with the scientific analysis of experimental data.

HTS Perspective

H To illustrate the relationships between the history of optics and the evolution of science and technology, using examples.

T To illustrate the use of optics in technical applications, using examples.

S To illustrate social changes associated with the use of optics, using examples.

TERMINAL OBJECTIVE 1

To analyze the propagation of light.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
1.1		To describe sources of natural and artificial light.	Nuclear light (stars), incandescent, fluorescent and phosphorescent sources, lasers
1.2		To connect the production of light with the transformation of other forms of energy.	Nuclear, electric and chemical energy
1.3	S	To illustrate social changes resulting from the use of artificial light, using examples.	Extended working hours, use of underground spaces, etc.
1.4		To explain how the eye perceives an object in terms of the direction of travel of light rays.	Light rays, direct and indirect sources of light
1.5	H	To illustrate how the interpretation of vision has evolved through history, using examples.	
1.6	EX	To observe the phenomena of umbra and penumbra in relation to the size of a light source and the distances between the source, the object and the screen.	Point sources, extended sources, light beam, pencil of light, light ray
1.7		To illustrate the phenomena of umbra and penumbra, using diagrams.	Ray diagrams
1.8		To explain the phenomena of solar and lunar eclipses.	
1.9		To establish the relationship between light intensity, distance from a source and the area lit, using the particle model of light.	Inversely proportional to the square of the distance
1.10		To solve problems related to the propagation of light.	Types of sources, umbra, penumbra, intensity, distance, area shaded, area illuminated, etc.

TERMINAL OBJECTIVE 2

To analyze the behaviour of light reflected from plane mirrors.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
2.1		To give examples of the phenomenon of reflection.	Mirrors, the Moon, illuminated objects
2.2		To compare diffuse reflection with specular reflection.	Nature of the reflecting surface
2.3		To illustrate the phenomenon of reflection in a plane mirror, using ray diagrams.	Incident rays and reflected rays, angle of incidence, angle of reflection, normal
2.4		To state the laws of reflection.	The angle of incidence is equal to the angle of reflection. The incident ray, the reflected ray and the normal are all on the same plane.
2.5		To illustrate the formation of an image in a plane mirror, using ray diagrams.	Location, attitude and magnification of the image
2.6	EX	To determine experimentally the paths of light rays and the field of vision produced by a plane mirror.	
2.7	T	To describe technical applications of plane mirrors, using examples.	Distance from the Earth to the Moon, reflex camera, sextant, periscope, two-way mirror, kaleidoscope, etc.
2.8		To solve problems related to reflection by plane mirrors.	Ray diagrams, images, laws of reflection, etc.

TERMINAL OBJECTIVE 3

To analyze the behaviour of light reflected from curved mirrors.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
3.1		To give examples of the use of curved mirrors.	Telescopes, make-up mirrors, rear view mirrors, surveillance mirrors, automobile headlights, flashlights, etc.
3.2		To illustrate the characteristics of a curved mirror, using a diagram.	Convex and concave mirrors, focus, principal axis, focal length, radius of curvature, centre of curvature
3.3		To compare the characteristics and limitations of the use of spherical mirrors and parabolic mirrors.	Spherical aberration
3.4	EX	To establish a qualitative relation, based on observations, between the position of an object and the characteristics of its image in a concave mirror.	Inverted or upright image, size of image, magnification
3.5		To distinguish a real image from a virtual image.	Comparison of convex and concave mirrors
3.6		To estimate the location and characteristics of the image formed by a concave mirror and a convex mirror, using the paths of the principal rays.	Principal rays; location, attitude and magnification of the image
3.7		To determine algebraically the location and characteristics of an image formed by a concave mirror.	$h_i / h_o = d_i / f = f / d_o$ $1 / d_o + 1 / d_i = 1 / f$ $M = h_i / h_o$
3.8	T	To describe the path of light in a Newtonian telescope.	
3.9	T	To describe technical applications of curved mirrors, using examples.	Telescopes, make-up mirrors, rear view mirrors, surveillance mirrors, automobile headlights, flashlights, etc.

TERMINAL OBJECTIVE 3 (cont.)

To analyze the behaviour of light reflected from curved mirrors.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
3.10	S	To describe social changes related to the use of curved mirrors.	International cooperation (Canada-France-Hawaii telescope, etc.)
3.11		To solve problems related to curved mirrors.	Ray diagrams, algebraic method, etc.

TERMINAL OBJECTIVE 4

To analyze the behaviour of light refracted by different substances.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
4.1		To describe the behaviour of light as it passes from one medium to another.	Less refractive medium to more refractive medium and vice-versa
4.2		To draw incident rays and refracted rays passing from one medium to another.	Angle of incidence, angle of refraction
4.3	EX	To determine experimentally the index of refraction for a substance.	
4.4		To explain the phenomenon of refraction.	Speed of light in different media
4.5		To state the laws of refraction.	$n_1 \sin\theta_1 = n_2 \sin\theta_2$ The incident ray, the refracted ray and the normal are in the same plane.
4.6		To describe the path of light in a prism, by drawing rays.	
4.7		To determine the critical angle in relation to two media, using the laws of refraction.	Angle of refraction = 90°
4.8		To explain the phenomenon of total internal reflection.	Critical angle
4.9	T	To describe the uses of total internal reflection in technology.	Binoculars, fibre optics, etc.
4.10	S	To describe social changes related to the use of fibre optics in technology.	Communications, medical technologies, etc.
4.11		To solve problems related to refraction.	Path of rays, laws of refraction, total internal reflection, etc.

TERMINAL OBJECTIVE 5

To analyze the behaviour of light travelling through lenses.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
5.1		To distinguish different types of lenses.	Double convex lens, double concave lens, plano-convex, plano-concave, converging meniscus, diverging meniscus
5.2		To draw a diagram illustrating the characteristics of lenses.	Converging and diverging lenses, optical centre, focal length, principal axis, principal focus
5.3	EX	To compare the optical power of two or more lenses of the same type, but with different curvatures.	Measurement of focal lengths
5.4		To determine the optical power of a lens and a system of lenses.	
5.5	H	To associate stages in the historical evolution of optical instruments with developments in physics.	Magnifying glass, corrective lenses, Galileo's telescope, camera, cinema, microscope, Hubble telescope, etc.
5.6	EX	To determine experimentally the characteristics of an image formed by a converging lens, according to the location of the object.	Location, magnification and orientation of the image
5.7		To draw ray diagrams to determine the location and characteristics of an image formed by thin converging and diverging lenses.	Location, magnification and orientation of the image
5.8		To determine algebraically the location and characteristics of an image formed by thin converging and diverging lenses.	Location, magnification and orientation of the image
5.9		To draw ray diagrams to compare the formation of images in the eye to the formation of images in a camera.	Camera lens and cristalline lens, film and retina, etc.
5.10	T	To illustrate the functions of lenses in optical instruments, using examples.	Microscope, telescope, astronomical telescope, camera, light sensor, stereoscopy, cinema, etc.

TERMINAL OBJECTIVE 5 (cont.)

To analyze the behaviour of light travelling through lenses.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
5.11	T	To associate eye defects with the appropriate correction techniques.	Myopia, presbyopia, hypermetropia, astigmatism, corrective lenses, contact lenses, surgery, etc.
5.12	S	To associate social changes with the development of optical instruments.	Cosmology, medicine, etc.
5.13		To solve problems related to lenses.	Ray diagrams, algebraic method, etc.

TERMINAL OBJECTIVE 6

To describe the electromagnetic spectrum and the applications of its various ranges.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
6.1	EX	To observe the dispersion of white light by a prism.	Crystals, light combinations, water droplets
6.2		To describe briefly the wave model of light.	Speed of light, visible spectrum, monochromatic and polychromatic light, wavelength, frequency
6.3		To explain the dispersion of white light through a prism, using the wave model of light.	Speed of light and wavelength
6.4		To describe the phenomenon of chromatic aberration produced by lenses.	Decomposition of white light
6.5		To explain how the colour of light and objects is perceived, in terms of the reflection and absorption of light.	Pigments, filters, transparent and opaque bodies, etc.
6.6	T	To describe briefly the laser and some of its applications.	Holography, optical sensors, military and medical applications, etc.
6.7		To classify different groups of waves according to their relative position in the electromagnetic spectrum.	Radio waves, microwaves, infrared rays, visible rays, ultraviolet rays, X-rays, gamma rays
6.8		To explain qualitatively the relation between the energy of a wave and the frequency of a wave (or its wavelength).	Comparison of different parts of the spectrum
6.9	T	To associate technology related to invisible waves with the laws of reflection.	Radio telescope, radar, parabolic antenna, remote sensing
6.10	T	To describe some of the applications and phenomena related to the various ranges of the electromagnetic spectrum, using examples.	Spectroscopy, X-rays, radioactivity, infrared detector, microwave oven, greenhouse effect, thinning of the ozone layer, etc.

TERMINAL OBJECTIVE 6 (cont.)

To describe the electromagnetic spectrum and the applications of its various ranges.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
6.11		To briefly describe the dual nature of light.	Modern physics, wave/particle duality
6.12	H	To associate historical discoveries with the evolution of knowledge related to the nature of light.	
6.13		To solve problems related to the electromagnetic spectrum and applications associated with its various ranges.	

EXPERIMENTAL METHOD

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

A1 To become familiar with the scientific method.

A1.1 To use experimentation as a means of exploration.

A1.2 To use experimentation to establish a simple relationship between two parameters.

A2 To become familiar with the technique for writing up an experimental procedure.

A2.1 To understand the need to explore one relationship at a time.

A2.2 To identify the constant parameters, the independent variable and the dependent variable.

A3 To become familiar with the technique for carrying out an experiment.

A3.1 To follow a simple experimental procedure.

A3.2 To observe a phenomenon in an experiment.

A3.3 To handle equipment in a simple experiment.

A3.4 To become familiar with measurement.

A4 To become familiar with the scientific analysis of experimental data.

A4.1 To present experimental data in a double-entry table.

A4.2 To process experimental data.

A4.3 To deduce a simple relationship from experimental data.

RELATIONSHIPS BETWEEN THE OBJECTIVES ASSOCIATED WITH

RELATED CONTENT		EXPERIMENTAL METHOD			
1.6	To observe the phenomena of umbra and penumbra in relation to the size of a light source and the distances between the source, the object and the screen.	A1		A3	A4
2.6	To determine experimentally the paths of light rays and the field of vision produced by a plane mirror.	A1	A2	A3	A4
3.4	To establish a qualitative relation, based on observations, between the location of an object and the characteristics of its image in a concave mirror.	A1		A3	A4
4.3	To determine experimentally the index of refraction for a substance.	A1	A2	A3	A4
5.3	To compare the optical power of two or more lenses of the same type, but with different curvatures.	A1	A2	A3	A4
5.6	To determine experimentally the characteristics of an image formed by a converging lens, according to the location of the object.	A1		A3	A4
6.1	To observe the dispersion of white light by a prism.	A1		A3	

HISTORY-TECHNOLOGY-SOCIETY PERSPECTIVE

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

H To illustrate the relationships between the history of optics and the evolution of science and technology, using examples.

1.5 To illustrate how the interpretation of vision has evolved through history, using examples.

5.5 To associate stages in the historical evolution of optical instruments with developments in physics.

6.12 To associate historical discoveries with the evolution of knowledge related to the nature of light.

T To illustrate the use of optics in technical applications, using examples.

2.7 To describe technical applications of plane mirrors, using examples.

3.8 To describe the path of light in a Newtonian telescope.

3.9 To describe technical applications of curved mirrors, using examples.

4.9 To describe the uses of total internal reflection in technology.

5.10 To illustrate the functions of lenses in optical instruments, using examples.

5.11 To associate eye defects with the appropriate correction techniques.

6.6 To describe briefly the laser and some of its applications.

6.9 To associate technology related to invisible waves with the laws of reflection.

6.10 To describe some of the applications and phenomena related to the various ranges of the electromagnetic spectrum, using examples.

S To illustrate social changes associated with the use of optics, using examples.

1.3 To illustrate social changes resulting from the use of artificial light, using examples.

3.10 To describe social changes related to the use of curved mirrors.

4.10 To describe social changes related to the use of fibre optics in technology.

5.12 To associate social changes with the development of optical instruments.

COURSE 2

KINEMATICS AND MOMENTUM

By learning about the scientific method, students will gain a better understanding of kinematics and momentum, as well as of technical phenomena and social changes associated with the development of mechanics.

GENERAL OBJECTIVE

By learning about the scientific method, students will gain a better understanding of kinematics and momentum, as well as of technical phenomena and social changes associated with the development of mechanics.

TERMINAL OBJECTIVES

Related Content

1 To analyze the concept of trajectory and the perception of motion.

2 To analyze a trajectory in terms of displacement, distance travelled and the successive positions of a moving object.

3 To analyze uniform rectilinear motion.

4 To analyze rectilinear motion with uniform acceleration.

5 To analyze the two-dimensional motion of projectiles.

6 To apply the principle of the conservation of momentum.

EX Experimental Method

B1 To apply the experimental method in simple cases.

B2 To write up a simple experimental procedure.

B3 To carry out a simple experiment.

B4 To analyze experimental data.

B5 To become familiar with the writing of a laboratory report.

HTS Perspective

H To illustrate the relationships between the history of kinematics and developments in physics, using examples.

T To illustrate the use of the principles of kinematics and momentum in practical situations, using examples.

S To illustrate social changes associated with the development of mechanics, using examples.

TERMINAL OBJECTIVE 1

To analyze the concept of trajectory and the perception of motion.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
1.1		To give examples of motion at different levels.	Vibration of molecules, motion of bacteria, transportation, planetary orbits, etc.
1.2	H	To place in historical perspective the scope of subjects covered by mechanics.	Earthly motion and celestial motion
1.3	S	To associate discoveries about the motion of heavenly bodies with the evolution of human perception of the universe.	
1.4		To define the concept of trajectory.	
1.5		To classify different types of motion according to their trajectories.	Rectilinear, curvilinear, circular, elliptic and random motion
1.6		To illustrate that the perception of motion and immobility depends on the point of view of the observer, using examples.	Observer on a train, basketball, orbit of planets, etc.
1.7		To describe the perception of various motions by means of the senses, using examples.	Perception by sight, smell, touch, hearing (Doppler effect)
1.8		To solve problems related to the concept of trajectory and the perception of motion.	

TERMINAL OBJECTIVE 2

To analyze a trajectory in terms of displacement, distance travelled and the successive positions of a moving object.

	INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
2.1	To distinguish displacement from distance travelled.	
2.2	To determine displacement and the distance travelled by a moving object.	Map drawn to scale, numerical data
2.3	To describe the magnitude and direction of displacement.	Points of the compass, Cartesian coordinates, polar coordinates
2.4	To draw a vector.	Magnitude, direction, tail and tip of a vector, scale, symbol
2.5	To distinguish a vector quantity from a scalar quantity.	
2.6	To add vectors.	Graphical method and component method
2.7	To explain why a description of a position requires a point of reference.	Relativity of position
2.8	To describe the successive positions of a moving object in a Cartesian context.	Rectilinear motion and two-dimensional motion
2.9	To solve problems related to position, displacement and the distance travelled.	Graphic and algebraic solutions, vector addition, etc.

TERMINAL OBJECTIVE 3

To analyze uniform rectilinear motion.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
3.1		To describe a rectilinear trajectory based on the corresponding "position-time" graph.	Construction and interpretation of a graph.
3.2		To establish a connection between the definition of velocity and its units of measurement.	$\vec{v} = \Delta\vec{d}/\Delta t$ Units: m/s, km/s, km/h
3.3		To describe uniform rectilinear motion.	Straight line, constant speed
3.4		To describe the shape of the "position-time" and "velocity-time" curves for uniform rectilinear motion.	Meaning of slope
3.5		To determine the equations for uniform rectilinear motion, based on graphs.	Slope, area below the curve; $\Delta\vec{d} = \vec{v}\Delta t$ v = constant
3.6		To use sign convention to describe uniform rectilinear motion.	Position, displacement, velocity
3.7		To describe different methods of measuring the speed of a moving object.	Stopwatch and ruler, stroboscope, Doppler effect, etc.
3.8	EX	To determine experimentally the equations of motion for an object in uniform rectilinear motion.	
3.9	H	To describe different methods used throughout history to measure the speed of light.	Galileo's attempts, astronomical method, etc.
3.10	S	To illustrate social changes and environmental consequences resulting from the development of means of rapid transport, using examples.	Urbanization, accessibility of goods and services, pollution, use of space, military development, etc.
3.11		To solve problems related to uniform rectilinear motion.	Algebraic and graphic solutions, sign convention, vectors, etc.

TERMINAL OBJECTIVE 4

To analyze rectilinear motion with uniform acceleration.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
4.1		To distinguish average velocity from instantaneous velocity.	
4.2		To establish a connection between the definition of acceleration and its units of measurement.	$\vec{a} = \Delta\vec{v}/\Delta t$ Units: m/s^2, km/h/s
4.3		To describe rectilinear motion with uniform acceleration.	Straight line, velocity with regular variation
4.4		To describe the shape of the "position-time," "velocity-time" and "acceleration-time" curves for rectilinear motion with uniform acceleration.	Constant acceleration, non-linear variation of displacement, linear variation of velocity
4.5		To determine the equations for rectilinear motion with uniform acceleration, based on graphs.	Slope, area below the curve; a = constant $\Delta\vec{v} = \vec{a}\Delta t$ $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
4.6		To use sign convention to describe rectilinear motion with uniform acceleration.	Position, displacement, velocity, acceleration
4.7	EX	To determine experimentally the equations of motion for an object in rectilinear motion with uniform acceleration.	
4.8		To compare the trajectories, graphs and equations for uniform rectilinear motion with those for rectilinear motion with uniform acceleration.	Table of comparisons
4.9		To analyze the motion of an object in free fall.	Gravitational acceleration, zero position, etc.
4.10		To describe the influence of air resistance on the motion of an object.	Parachute, airplane, automobile, etc.
4.11		To solve problems related to rectilinear motion with uniform acceleration.	Algebraic and graphic solutions, vectors, sign convention, free fall, etc.

TERMINAL OBJECTIVE 5

To analyze the two-dimensional motion of projectiles.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
5.1		To distinguish the trajectory of rectilinear motion from that of the motion of a projectile.	Straight line, (one dimension), parabola (two dimensions)
5.2		To resolve the two-dimensional motion of a projectile into two perpendicular rectilinear motions.	Uniform horizontal component, uniformly accelerating vertical component
5.3		To determine the characteristics of the motion of a projectile.	Initial velocity, range, maximum height
5.4		To write the equations of motion for a projectile.	$\Delta\vec{d}_x = \vec{v}_x \Delta t$ and v_x = constant $\Delta\vec{d}_y = \vec{v}_{yi} \Delta t + ½ \vec{a} \Delta t^2$ and $\vec{v}_y = \vec{v}_{yi} + \vec{a}_y \Delta t$ $g = 9.8$ m/s^2
5.5	T	To describe some real-life examples of the motion of projectiles, using examples.	Launching of a shell, archery, baseball, airdrop of goods, etc.
5.6	H	To associate discoveries in kinematics with developments in physics.	Work of Aristotle, Copernicus, Galileo, Newton, etc.
5.7		To solve problems related to projectiles.	Graphic and algebraic solutions, instantaneous values, etc.

TERMINAL OBJECTIVE 6

To apply the principle of the conservation of momentum.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
6.1		To establish a connection between the definition of momentum and its units of measurement.	$\vec{p} = m\vec{v}$ Units: kg•m/s
6.2		To state the principle of the conservation of momentum.	p_{total} = constant; concept of system
6.3	EX	To use inductive reasoning to derive the law of conservation of momentum from experimental data.	Perfectly elastic collision in a two-dimensional system
6.4	T	To illustrate applications of the principle of conservation of momentum, using examples.	Collisions, rocket propulsion, explosions, etc.
6.5		To solve problems related to the conservation of momentum in a one-dimensional and a two-dimensional system.	Perfectly elastic and perfectly inelastic collisions, applications, etc.

EXPERIMENTAL METHOD

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

B1 To apply the experimental method in simple cases.

B1.1 To use experimentation to establish a mathematical relationship between parameters.

B1.2 To use experimentation to discover a law by inductive reasoning.

B2 To write up a simple experimental procedure.

B2.1 To distinguish the object of the experiment from the parameters measured.

B2.2 To determine the independent variable, the dependent variable and the constant parameters.

B2.3 To become familiar with the writing of procedures.

B3 To carry out a simple experiment.

B3.1 To develop the skill of handling experimental equipment.

B3.2 To gather experimental data taking into account experimental uncertainty in writing the numerical data.

B4 To analyze experimental data.

B4.1 To identify the causes of experimental errors.

B4.2 To distinguish between experimental error and experimental uncertainty.

B4.3 To identify the causes of experimental errors.

B4.4 To take significant digits into account when processing data.

B4.5 To interpret graphs and all experimental data rigorously.

B5 To become familiar with the writing of a laboratory report.

B5.1 To be familiar with the role of a laboratory report.

B5.2 To be familiar with the parts of a laboratory report.

B5.3 To discuss an experiment and write a conclusion.

RELATIONSHIPS BETWEEN THE OBJECTIVES ASSOCIATED WITH RELATED CONTENT AND WITH THE EXPERIMENTAL METHOD

RELATED CONTENT		EXPERIMENTAL METHOD				
3.8	To determine experimentally the equations of motion for an object in uniform rectilinear motion.	B1	B2	B3	B4	
4.7	To determine experimentally the equations of motion for an object in rectilinear motion with uniform acceleration.	B1	B2	B3	B4	B5
6.3	To use inductive reasoning to derive the law of conservation of momentum from experimental data.	B1			B4	B5

HISTORY-TECHNOLOGY-SOCIETY PERSPECTIVE

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

H To illustrate the relationships between the history of kinematics and developments in physics, using examples.

1.2 To place in historical perspective the scope of subjects covered by mechanics.

3.9 To describe different methods used throughout history to measure the speed of light.

5.6 To associate discoveries in kinematics with developments in physics.

T To illustrate the use of the principles of kinematics and momentum in practical situations, using examples.

5.5 To describe some real-life examples of the motion of projectiles, using examples.

6.4 To illustrate applications of the principle of conservation of momentum, using examples.

S To illustrate social changes associated with the development of mechanics, using examples.

1.3 To associate discoveries about the motion of heavenly bodies with the evolution of human perception of the universe.

3.10 To illustrate social changes and environmental consequences resulting from the development of means of rapid transport, using examples.

COURSE 3

FORCES AND ENERGY

By learning about the scientific method, students will gain a better understanding of dynamics, and of technical phenomena, environmental consequences and social changes associated with the development of dynamics.

GENERAL OBJECTIVE

By learning about the scientific method, students will gain a better understanding of dynamics, and of technical phenomena, environmental consequences and social changes associated with the development of dynamics.

TERMINAL OBJECTIVES

Related Content

1 To describe the concept of force and the consequences of applying force to an object.

2 To explain gravitational force and its characteristics.

3 To explain the effects of a force on the motion of an object (Newton's Second Law).

4 To explain the motion of an object as a function of work, energy and the conservation of energy.

5 To explain friction between two surfaces and air resistance on objects in motion.

6 To explain Archimedes' Principle.

7 To explain the extension of a spring and pressure.

8 To explain the operation of simple and compound machines.

EX Experimental Method

C1 To apply the experimental method.

C2 To write up an experimental procedure.

C3 To carry out an experiment.

C4 To write a laboratory report.

HTS Perspective

H To illustrate the relationships between the history of dynamics and developments in physics and technology, using examples.

T To illustrate the use of dynamics in technical applications, using examples.

S To illustrate social changes and environmental consequences associated with the use of dynamics, using examples.

TERMINAL OBJECTIVE 1

To describe the concept of force and the consequences of applying force to an object.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
1.1		To distinguish basic forces in terms of their scale.	Nuclear force, electromagnetic force and gravitational force
1.2	H	To describe briefly the direction of current research in physics on basic forces.	Unified theory
1.3		To distinguish a force acting at a distance from a contact force.	
1.4		To define the concept of force.	Meaning in physics and in ordinary language
1.5		To describe the effects of applying a force to an object.	Deformation, acceleration
1.6		To state Newton's three laws.	In the absence of an unbalanced external force, an object remains at rest, or continues in uniform rectilinear motion. $\vec{F} = m\vec{a}$; $\vec{F}_{action} = -\vec{F}_{reaction}$
1.7		To interpret Newton's First Law as a special case of his second law.	
1.8		To give examples of applications of Newton's Third Law.	
1.9		To determine the relationship between the units of measurement of force and Newton's Second Law.	1 N = 1 kg•m/s^2, $\vec{F} = m\vec{a}$
1.10		To express force as a vector quantity.	Sign, representation, point of application
1.11		To solve problems related to the concept of force and the effects of applying a force to an object.	Force vector, Newton's laws, etc.

TERMINAL OBJECTIVE 2

To explain gravitational force and its characteristics.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
2.1		To describe the effects of gravitational attraction.	Falling objects and the motion of planets.
2.2		To draw a vector to represent gravitational force in various situations.	
2.3		To describe the operation of a spring scale, giving examples.	
2.4	EX	To determine experimentally the relationship between mass and gravitational force, using a spring scale (dynamometer).	$\vec{F}_g \propto m$ $\vec{F}_g = P = m\vec{g}$ $\quad g = 9.8$ m/s^2
2.5		To distinguish between mass and weight.	Meaning in physics and in ordinary language
2.6		To explain the variations of gravitational acceleration in different parts of the world.	
2.7	T	To describe the possibilities for microgravity research and related technical applications.	Plant cultivation in a weightless environment, astronauts' experience, new materials, etc.
2.8		To compare gravitational force with electrical force.	Equation, attraction, repulsion, etc.
2.9		To describe natural phenomena in terms of gravitational attraction.	Tides, black holes, etc. Weight, attraction between Earth and Moon, etc. $F_g \quad G\frac{m_1 m_2}{d^2}$
2.10	H	To describe important stages in the development of knowledge about gravitational force.	Work of Galileo, Newton and Einstein.
2.11		To solve problems related to gravitational force and its manifestations.	

TERMINAL OBJECTIVE 3

To explain the effects of a force on the motion of an object (Newton's Second Law).

		INTERMEDIATE OBJECTIVE	ADDITIONAL INFORMATION
3.1		To establish the relationship between force and momentum.	$\vec{F} = \Delta\vec{p}/\Delta t = m\vec{a}$
3.2		To represent graphically and algebraically the forces present in different situations.	
3.3		To write equations for the motion that results from applying a force to an object.	a = constant $\Delta\vec{v} = \vec{a}\Delta t$ $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\Delta t^2$
3.4	EX	To prove Newton's Second Law in an experiment.	
3.5		To write equations for the motion that results from applying several forces simultaneously to an object.	Vector addition: $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + ... \vec{F}_n = m\vec{a}$
3.6		To describe the conditions for equilibrium of forces.	$F_{net} = 0$, geometric representation
3.7		To solve problems related to Newton's Second Law.	Net acceleration, equilibrant force, free fall, etc.

TERMINAL OBJECTIVE 4

To explain the motion of an object as a function of work, energy and the conservation of energy.

	INTERMEDIATE OBJECTIVE	ADDITIONAL INFORMATION
4.1	To associate the definition of kinetic energy with its units of measurement.	$E_k = \frac{1}{2}mv^2$ Unit: joule
4.2	To associate the definition of potential energy with its units of measurement.	$E_g = mgh$ Unit: joule
4.3	To describe the energy transformations undergone by a moving object.	Free fall, projectiles, etc.
4.4	To use the principle of the conservation of energy in different situations.	Free fall, projectile, inclined plane, etc.
4.5	To define the concept of work in mechanics.	$W = F \ \Delta d$ Meaning in physics and in ordinary language
4.6	To solve problems related to mechanical work, energy and conservation of energy.	

TERMINAL OBJECTIVE 5

To explain friction between two surfaces and air resistance on objects in motion.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
5.1		To draw vectors of frictional force for different situations.	Point of application, magnitude, direction
5.2	EX	To determine experimentally the factors affecting the friction between two surfaces.	Nature of surface, area of contact, mass of the object, etc.
5.3		To analyze the motion of an object, taking friction into account.	Acceleration, net force, etc.
5.4		To describe the difference between static friction and kinetic friction, using examples.	
5.5		To describe the parameters affecting air resistance and their effect on motion, using examples.	Speed, air density, surface area exposed, braking, heating
5.6		To draw force vectors associated with air resistance in different situations.	
5.7		To analyze the motion of an object, taking air resistance into account.	Acceleration, terminal velocity, net force, etc.
5.8	H	To associate historical facts with the development of knowledge about aerodynamics.	
5.9	T	To describe applications that make use of knowledge about friction or air resistance, using examples.	Skis, tires, skates, arrow, boomerang, airplane, automobile, sailboat, etc.
5.10	S	To associate social changes and environmental consequences with the development of aerodynamics.	
5.11		To solve problems related to friction and air resistance.	Net force, terminal velocity, etc.

TERMINAL OBJECTIVE 6

To explain Archimedes' Principle.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
6.1		To associate Archimedean buoyant force with everyday phenomena.	Flotation, apparent weight
6.2	EX	To determine experimentally the factors affecting Archimedean buoyant force.	
6.3		To establish a relation between the definition of density and its units of measurement.	$\rho = m/V$ Units: g/cm^3, kg/m^3
6.4		To state Archimedes' Principle by associating it with its corresponding equation.	$\vec{F}_b = \rho V \vec{g}$
6.5		To describe the behaviour of an object submerged in a liquid in terms of the relation between its density and the density of the liquid.	Floating and non-floating objects, submerged portion of an iceberg, etc.
6.6		To explain the operation of a hydrometer, using examples.	
6.7	T	To illustrate applications of Archimedes' Principle, using examples.	Submersion and resurfacing of a submarine, etc.
6.8		To solve problems related to Archimedes' Principle.	

TERMINAL OBJECTIVE 7

To explain the extension of a spring and pressure.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
7.1	EX	To determine experimentally the relationship between applied force and extension for a spring.	
7.2		To establish a connection between the definition of applied force and its units of measurement.	$F = kx$; units of k
7.3		To analyze different situations that involve the force applied to a spring.	
7.4		To apply the concepts of work, potential energy and kinetic energy to the extension of a spring.	$E_p = ½\ kx^2$
7.5	T	To give examples of various types of springs and their uses.	Coil, conical and leaf springs, spring scale (dynamometer), automobile suspension, etc.
7.6		To establish a connection between the definition of pressure and its units of measurement.	$p = F/A$ Unit: Pa (N/m^2)
7.7		To analyze different situations that involve pressure.	Pressure exerted by a solid or a liquid, transmission of pressure, etc.
7.8		To describe the operation of a manometer.	
7.9	T	To describe briefly the operation of a hydraulic lift cylinder.	Hydraulic lift in a garage, heavy machinery, etc.
7.10		To solve problems related to the extension of springs and pressure.	Hooke's Law, work, conservation of energy, force, pressure, transmission of pressure, etc.

TERMINAL OBJECTIVE 8

To explain the operation of simple and compound machines.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
8.1		To distinguish a simple machine from a compound machine.	
8.2	EX	To use inductive reasoning to derive the law of levers, based on an experiment.	$F_E \ell_E = F_R \ell_R$
8.3		To describe the operation of different types of levers.	Fulcrum, resistance force, effort force, resistance distance, effort arm, first-, second- and third-class levers
8.4		To calculate the mechanical advantage of a machine.	Effort force, resistance force
8.5		To compare a wheel with a first-class lever.	Radius = effort arm
8.6		To compare the mechanical advantage of a fixed pulley with that of a moveable pulley.	
8.7		To describe the operation of a pulley block and a hoist.	
8.8		To describe the use of inclined planes and their advantages, using examples.	
8.9	T	To describe the operation of different types of mechanical transmission.	Chain, belt, gear, universal joint
8.10		To calculate the efficiency of a machine.	Work output/work input
8.11	H	To illustrate important stages in the technical evolution of machines, using examples.	Work of Archimedes, Leonardo da Vinci, Fulton, Diesel, Jacquard, Ford, Bombardier
8.12	S	To relate social changes and environmental consequences to the development and applications of dynamics.	Industrial revolution, means of transport, etc.
8.13		To solve problems related to simple and compound machines.	Work, energy, mechanical advantage, power, efficiency, etc.

EXPERIMENTAL METHOD

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

C1 To apply the experimental method.

C1.1 To use experimentation to establish a relationship between two parameters.

C1.2 To use experimentation as a means of verification.

C1.3 To use experimentation as a means of exploration.

C2 To write up an experimental procedure.

C2.1 To choose the equipment necessary for an experiment.

C2.2 To determine the stages of the work.

C2.3 To write up the procedure clearly.

C3 To carry out an experiment.

C3.1 To follow their own written experimental procedure.

C3.2 To handle the equipment correctly.

C3.3 To take the appropriate measures, taking experimental error into account.

C4 To write a laboratory report.

C4.1 To be familiar with the structure of a laboratory report.

C4.2 To describe the experiment performed: goals, equipment, steps, diagram.

C4.3 To present the results of the experiment.

C4.4 To present a rigorous analysis of the results.

C4.5 To discuss the results.

C4.6 To write the conclusions of an experiment clearly, relating them to the problem stated.

C4.7 To clearly and logically present all the parts of a report.

RELATIONSHIPS BETWEEN THE OBJECTIVES ASSOCIATED WITH RELATED CONTENT AND WITH THE EXPERIMENTAL METHOD

RELATED CONTENT		EXPERIMENTAL METHOD			
2.4	To determine experimentally the relationship between mass and gravitational force, using a spring scale (dynamometer).	C1		C3	C4
3.4	To prove Newton's Second Law in an experiment.	C1	C2	C3	C4
5.2	To determine experimentally the factors affecting the friction between two surfaces.	C1		C3	C4
6.2	To determine experimentally the factors affecting Archimedean buoyant force.	C1	C2	C3	C4
7.1	To determine experimentally the relationship between applied force and extension for a spring.	C1	C2	C3	C4
8.2	To use inductive reasoning to derive the law of levers, based on an experiment.	C1	C2	C3	C4

HISTORY-TECHNOLOGY-SOCIETY PERSPECTIVE

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

H To illustrate the relationships between the history of dynamics and developments in physics and technology, using examples.

1.2 To describe briefly the direction of current research in physics on basic forces.

2.10 To describe important stages in the development of knowledge about gravitational force.

5.8 To associate historical facts with the development of knowledge about aerodynamics.

8.11 To illustrate important stages in the technical evolution of machines, using examples.

T To illustrate the use of dynamics in technical applications, using examples.

2.7 To describe the possibilities for microgravity research and related technical applications.

5.9 To describe applications that make use of knowledge about friction or air resistance, using examples.

6.7 To illustrate applications of Archimedes' Principle, using examples.

7.5 To give examples of various types of springs and their uses.

7.9 To describe briefly the operation of a hydraulic lift cylinder.

8.9 To describe the operation of different types of mechanical transmission.

S To illustrate social changes and environmental consequences associated with the use of dynamics, using examples.

5.10 To associate social changes and environmental consequences with the development of aerodynamics.

8.12 To relate social changes and environmental consequences to the development and applications of dynamics.

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