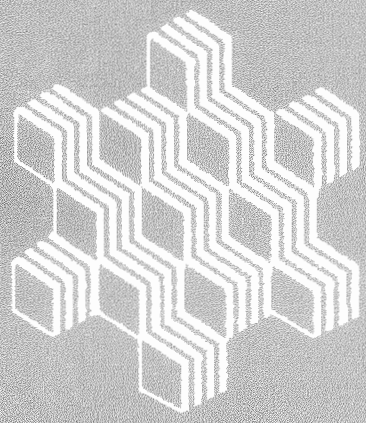
Secondary School Curriculum



PHYSICS 534

THE DISCOVERY OF MATTER AND ENERGY

Québec

Secondary School Curriculum

PHYSICS 534

THE DISCOVERY OF MATTER AND ENERGY

Direction générale des programmes
Direction de la formation générale des jeunes

Approved by the Comité protestant and the Comité catholique of the Conseil supérieur de l'éducation on December 11, 1991 and January 27, 1992.

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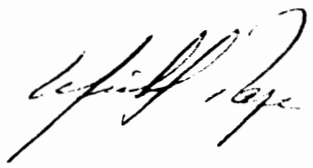

Michel Pagé
Minister of Education

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Authors:

Denis Chabot
Coordinator for Natural
Science Programs
Ministère de l'Éducation

Raymond Gervais
Education Consultant - Natural Sciences
CS Jérôme-Le Royer

Bernard Tousignant
Science Teacher (Physics)
CS Trois-Rivières

Contributors:

Claude Délisle
Science Teacher (Chemistry)
CECM

Ken Tannahill
Science Teacher (Physics)
CS District of Bedford

English Version:

Direction du développement pédagogique en langue anglaise (DDPLA)

Translation:

William Gore, Allan Van Meer and Joanne Akai

Suggested References:

Vincent Ranellucci
Science Teacher (Physics and Chemistry)
Lakeshore School Board

Word Processing:

Lise Colanero
Brigitte Lamarre

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FOREWORD

This document is the program-guide for Physics 534. This program is intended for Secondary V students who have passed Secondary IV Physical Sciences 436 (enriched path) and who plan on opting for the cégep-level Pure and Applied or Health Science concentrations, certain vocational education programs or certain other cégep programs. This program is also open to Secondary IV students who have passed Physical Sciences 436 and who simply wish to continue developing knowledge, skills and attitudes related to the study of the physical properties of matter.

This program-guide was developed by the Direction de la formation générale des programmes and is intended for Physics teachers; it outlines the compulsory and optional (enrichment) content of the program. Directors of educational services, teaching coordinators and education consultants specializing in the field of natural sciences should refer to this document when preparing and conducting information sessions and in-service training activities related to this program.

As explained in Chapter 8 of this document, each school board is responsible for organizing the pedagogical support and providing the materials needed to help students attain the objectives of the program. Teachers, with the help of education consultants, are free to determine which enrichment activities will be offered to students who have the time and who are willing and able to go beyond the compulsory material. Teachers can use the optional objectives in this program-guide (those preceded by two asterisks **) or develop their own enrichment activities.

This document defines the knowledge, skills and attitudes that students should develop in this program. Each intermediate objective suggests a series of learning activities and teaching strategies as well as other information that can help teachers plan their lessons and carry out formative evaluation of student learning.

1. INTRODUCTION

1.1 Background

A comprehensive survey of the educational community conducted by the ministère de l'Éducation in 1977 revealed that the curriculum no longer met the needs of students or of society in general. Thus, in 1978, the Ministère began to revise all elementary- and secondary-school programs.

A *Plan of Action*[1], published in 1979, redefined the objectives of Québec education and suggested ways of dealing with certain problems identified by the educational community and society in general. The *Plan of Action* also outlined compulsory and optional programs for each year of elementary and secondary school.

First published in 1981 and revised in 1986 and again in 1990, the *Basic School Regulations*[2] now make it compulsory for Secondary IV students to pass a six-credit science course covering the basic principles of physics and chemistry in order to obtain a Secondary School Diploma. Students can choose either the regular path (Physical Sciences 416) or the enriched path (Physical Sciences 436) of this course. Those who pass Physical Sciences 436 can take Secondary V Physics (Physics 534) and Secondary V Chemistry (Chemistry 534).

1.2 Analysis of the Situation

In 1986, the Direction des programmes held wide-ranging consultations with science educators because it felt that physics and chemistry programs had undergone substantial change. A major part of this consultation process was a formal needs analysis whose purpose was to

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[1] Québec, ministère de l'Éducation, *The Schools of Québec: Policy Statement and Plan of Action*, Code 49-1070A (Québec: ministère de l'Éducation, 1979).

[2] Québec, ministère de l'Éducation, Direction générale du développement pédagogique, *Basic School Regulation for Secondary School Education*, 1991. This is the English translation of the *Régime pédagogique*.

determine the orientations and content of the new programs, to establish priorities, and to ensure that secondary-level courses were compatible with cégep programs.

This needs analysis led to the publication of the document *New Physical Sciences Programs: Key Issues and Rationale*,[3] which describes the current situation regarding physics and chemistry programs and specifies the measures and the orientations needed to improve the situation. This document served as a basis for further consultation with the various educators and officials involved in this matter.

The findings in the Information Document are also based on a variety of studies concerning science education. Included among these are the Rapport Evalensci, the analysis of the ASOPE, the Projet de l'orientation de l'éducation scientifique prepared by the Direction générale du développement pédagogique, the reports submitted by the Association des professeurs de sciences du Québec, various studies on science education and scientific knowledge such as those prepared by Jacques Désautels, Pierre-Léon Trempe and their associates, the advisory documents published by the Conseil supérieur de l'éducation, the report by the Science Council of Canada and the report on science education in French Canada. The development of this program-guide is based on this work and on comparative studies concerning science education in Québec and elsewhere.

1.2.1 CURRENT SITUATION

During the 1960s and 1970s, Secondary V physics programs were greatly influenced by the P.S.S.C. method developed in the United States. In the 1960s, this method was used with secondary school students who planned to study science at the post-secondary level. After cégeps were created, this method was used with gifted Secondary IV and V science students. At that time, descriptive teaching methods for physics gave way to methods that focused on the explanation of phenomena. The subject matter, however, did not always reflect the students' level of intellectual development.

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[3] Québec, ministère de l'Éducation, Direction de la formation générale, *New Physical Sciences Programs: Key Issues and Rationale*, Code 72-0004 (Québec: ministère de l'Éducation, 1987). Hereafter referred to as the Information Document.

The teaching time allotted to this discipline gradually decreased without a corresponding reduction in the amount of subject matter that students were expected to cover. Teaching styles were influenced by the fact that ministry-and locally-prepared evaluation instruments mainly assessed the student's knowledge, with little concern for the development of skills and attitudes. This situation made it difficult for teachers to adopt teaching strategies based on the experimental method. The subject matter was presented as a set of absolute objective truths, and students became passive consumers of knowledge rather than active architects of their own scientific education. As a result, little time was devoted to the development of scientific skills and attitudes.

In addition, it seems that students start out with positive attitudes towards science. However, these attitudes gradually change so that by the end of secondary school, students have lost interest in science as it is currently taught. They view science as an incomprehensible set of formal procedures, as an arid examination of things that is based on spurious assumptions and divorced from the human aspects of modern life. Therefore, it should come as no surprise that Québec universities do not produce the number of scientists required in a modern society.

1.2.2 DESIRED SITUATION

The Secondary V Physics program should provide young Quebecers with the background they need to continue studying sciences at the post-secondary level, while preparing them to meet the challenges of everyday life that are strongly influenced by scientific and technological discoveries. By studying physics, young people will be better equipped to participate in decision-making processes that will affect the future of humanity.

In order to breathe new life into physics courses and to make them appealing to students, educators must design programs that are in tune with the basic realities of modern society. A knowledge of science, complemented by a strong sense of ethics, is one of the key elements in a person's development and one of the major components of fundamental education. Furthermore, a society can express its cultural identity only in conjunction with some form of scientific and technological autonomy.

Consequently, when conducting scientific activities, it is important to refer to the history of science as well as current social and environmental issues. This approach is now regarded as an effective way of encouraging young people to work for change. Although secondary-level physics courses should prepare students for a career, they should above all motivate them to become responsible citizens of the world.

In addition, the initial training of science teachers, social values and prejudices and methods of evaluation are some of the many powerful influences that make it difficult to alter our approach to physics teaching. However, such change is essential. It is important to bear in mind that this goal can be achieved only if society as a whole learns to value scientific and technological education.

1.3 Relationship with Other Programs

Physics 534 is the continuation of Physical Sciences 436; both programs are based on the same foundations and orientation. Students will be able to use and reinforce what they have learned since elementary school (i.e. skills and attitudes associated with the scientific method, sense of ethics, concern for the environment, knowledge of natural phenomena and technology related to physics). They will also apply some of the principles and concepts studied in earlier biology and mathematics programs. Finally, this program familiarizes young people with specific work methods, thought processes and related content, thereby preparing them for physics and certain vocational programs offered at the post-secondary level.

2. ORIENTATIONS OF THE PROGRAM

2.1 Values

This program promotes a set of values reflecting a certain view of science and a conception of the type of person that should emerge from this course. The values listed below can be regarded as the different facets of science education that Secondary V students will be able to develop as they investigate natural phenomena and technology associated with physics. In so doing, young people will be prepared to meet the challenges of the future.

- Intellectual Values:
  - methodical and rigorous work habits
  - an interest in research
  - a constant search for the truth

- Social and Cultural Values:
  - recognition that the search for scientific and technological knowledge is a cultural activity
  - a concern for providing young men and women with equal opportunities in the field of science and technology
  - international solidarity in dealing with today's major problems
  - an understanding of nature
  - team spirit
  - a concern for correct language

- Moral Values:
  - respect for life and for the environment
  - a sense of responsibility
  - a concern for health and safety
  - individual effort and self-discipline

The knowledge, skills and attitudes that students will acquire in this program are indissociable and reflect the values listed above.

2.2 Foundations

The content of this program-guide reflects recent findings in the fields of educational theory and epistemology even though these elements are difficult to incorporate into a program that is structured around learning objectives. The program is based on the following sociological, pedagogical and epistemological foundations.

2.2.1 SOCIOLOGICAL FOUNDATIONS

The principles of physics are applied in a variety of fields. Some of these applications are taken for granted (e.g. use of levers, binoculars and cameras), whereas others are less known (e.g. fibre optics and energy transformation devices). Nevertheless, they all in some way affect our lives, society as a whole and the environment.

There is no doubt that physics and related technologies are omnipresent in many aspects of our lives. Physics research and related technology spawn new activities which in turn lead to new research and technology. It is important to help students understand natural phenomena and technology related to physics and how to formulate equations, but it is equally important to make them aware that physics is very much concerned with the quality of human life. Students would certainly benefit from this knowledge. Young people are interested in learning about the many theoretical aspects and practical applications of physics.

By learning how physicists have contributed to our knowledge of the behaviour of matter and by conducting their own individual and group research and experiments, students will develop analytical, decision-making and communication skills and thereby become informed citizens.

2.2.2 PEDAGOGICAL FOUNDATIONS

It is generally agreed that people can master anything if they are given the opportunity to practise the theory. Over the last few decades, a great deal of research in the fields of science education and psychology has shown that students learn best when they are actively involved in the learning process. Thus it is important to ensure that students participate

physically and intellectually by adopting teaching methods that focus on the students and their intellectual abilities and interests, and not the learning content.

It is often mistakenly assumed that students will automatically learn what has been presented to them, remember what has been shown, apply the methods that have been demonstrated and adopt the values that have been promoted. Pedagogical research has shown that this is not the case. The teaching approach advocated by this program involves organizing learning situations that will enable the students to discover the structure of science in their own way and guiding them through their learning process. For the students, learning means actively participating in the learning process rather than passively absorbing copious amounts of information. This approach usually leads them to change their attitudes toward the sciences.

Some students who will be taking this course have not reached the formal operational stage of their development. Some may have basic cognitive difficulties or may not have developed their deductive reasoning abilities sufficiently. For this reason, an inductive approach should be adopted.

Students often indicate their interest in a subject by asking questions. If they are not sufficiently motivated to ask questions, it will be difficult to teach them anything meaningful. To spark this curiosity, the teacher should explain abstract concepts in terms of concrete situations relating to the students' environment, taking into account the knowledge, skills and attitudes they have already acquired.

The teacher should then help them construct the learning content by having them carry out concrete experiments that take into account their initial explanations or representations of a concept or phenomenon. If necessary, the teacher can provide demonstrations, simulations, preset procedures or other appropriate techniques to illustrate certain points. Finally, the teacher should conduct discussions so as to help students review the learning content and provide feedback.

To facilitate learning, teachers should choose their instructional approach carefully. When examining a problem with students, it is important to avoid shifting too quickly from the qualitative study of a question to the quantitative or mathematical approach normally used by physicists.

2.2.3 EPISTEMOLOGICAL FOUNDATIONS (NATURE AND ORIGIN OF SCIENTIFIC KNOWLEDGE)

Scientific knowledge is a product of human intellectual activity and its development is characterized by a series of mistakes, successes, dead ends, repetitions, gaps, setbacks and productive collaborations. Although it has evolved to deal with current problems, it is also deeply rooted in the past. It must be borne in mind that scientific knowledge is constructed by human beings and is not necessarily an absolute reflection of reality.

Thus, the teacher should encourage students to develop their own hypotheses, procedures, models and conclusions and allow them to reject, retain or refine them on the basis of their observations of the natural environment, discussions with their classmates, and generally accepted scientific principles. In this way, they will gradually become familiar with the strengths and limitations of the experimental approach and the relative merits of the different theories, and will learn to appreciate the work involved in looking for truths. Students should be given the opportunity to work like scientists.

According to this "constructivist" philosophy, scientific knowledge is constructed from human beings' intellectual efforts to acquire knowledge and understanding of natural and technological phenomena and technology on the basis of what is already known. Thus, the teacher should help the students apply what they already know to construct knowledge and to construct their own development.

2.3 Learning Content and Integrating Themes

This physics program is centred on the following integrating themes:

- "scientific" work methods, in particular the experimental method
- "scientific" ways of thinking, in particular the inductive method

The learning content includes:

- a more in-depth examination of the organization of concepts related to matter and energy by means of an investigation of natural phenomena and technology related to physics

- the concept of a model
- the nature of science itself

The students should construct the learning content by exploring their environment, examining the past and present interrelationships of science, technology and society, conducting laboratory experiments and working with computer simulations.

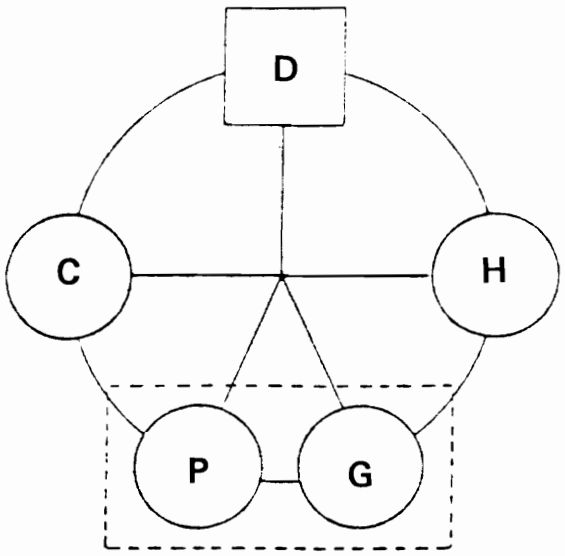
2.4 Learning Approach

To help students acquire the knowledge, skills and attitudes that will enable them to become more familiar with and understand the concepts of energy and matter in their environment, this program advocates a problem-solving approach to teaching physics. The topics should be presented as problems to be solved so that students learn how to link familiar concepts with new experiences and deal with information that may contradict their own intuitive ideas about natural phenomena and technology related to physics. Students should be encouraged to discuss a problem among themselves and to try to find a solution using a variety of investigative techniques. They then analyze their results to see whether they are at variance with their predictions and draw their own conclusions. This process may change their understanding of the concept or phenomenon they are studying. The knowledge, skills and attitudes they acquire through this exercise can help them deal with similar problems in or outside the classroom.

Since students are actively involved in finding their own solutions based on what they already know, they are constructing knowledge instead of passively assimilating facts. Consequently, what they learn will likely be more meaningful than the information they would receive in a more passive learning situation.

The following diagram illustrates the approach emphasized in this program. Each step is explained in detail. As with the acquisition of knowledge, this process is not necessarily linear, cumulative, or free of error and failure, especially since the students' thought processes are not always consistent with the rationale of the model described below.

DIAGRAM OF THE PROBLEM-SOLVING APPROACH



Verification = Analysis

Legend:

D: Defining the Problem
G: Gathering the Data
C: Conclusion
H: Formulating a Hypothesis
P: Processing the Data

DEFINING THE PROBLEM:

Students may have a variety of questions after observing natural or technological phenomena, making measurements, doing experiments, reading on a particular subject, working with audio-visual materials, reflecting on a topic or discussing it with other people. This is a sort of **cognitive gap** that students will attempt to bridge by trying to find the answers to these questions if they feel it is beneficial or to their advantage. The students begin by trying to define the problem as precisely as possible.

FORMULATING HYPOTHESES

The students formulate their reactions to the situation by proposing one or more solutions that they feel are plausible. These responses may be based on intuition, logical reasoning or explanations, but they should be regarded as tentative solutions to be analyzed and verified.

GATHERING THE DATA

The students look for and examine the data or sources of information related to the problem. This data can be obtained through observations, measurements, experiments, investigations, library research or other relevant techniques.

PROCESSING THE DATA

The students organize, classify, compare and interpret their data, checking it against their hypotheses. They then relate the data to the goal they are pursuing.

CONCLUSION

After analyzing their data, the students evaluate their hypotheses and present the results by writing a report, developing a model, formulating a law or a theory or by using any other appropriate method. They review the entire learning situation, examining the process and the product. Students should then apply the knowledge they have acquired to similar learning situations.

The above procedure is an attempt to describe how students learn through the problem-solving approach. They gradually become familiar with a work method that does not necessarily lead to the correct answer, but which enables them to acquire knowledge, skills and attitudes that will be invaluable throughout their lives.

This approach, which is often referred to as the "scientific method", is generally regarded as a problem-solving technique.

2.5 Teacher's Role (Instructional Approach)

Learning is defined as a dynamic process in which the students construct their own knowledge; as such the teacher's role is to guide the students through the learning process by teaching them how to learn, not what to learn. The teacher should encourage the students to develop their talents by choosing a variety of teaching strategies and the most appropriate learning activities. Teaching methods should be geared to the students' potential and should by no means be based on a single approach.

The challenge facing the teacher is to help students understand the principles of physics while making the learning process a fascinating experience. Students would find the study of physics more meaningful and fascinating if the learning content dealt with the environment and if they saw the close connection between physics and technology. It is important for students to understand the concepts, models and laws of physics, and this goal can best be achieved by relating the theory to natural and artificial objects in their environment. As such, students are given the opportunity to explore natural phenomena and technology related to physics.

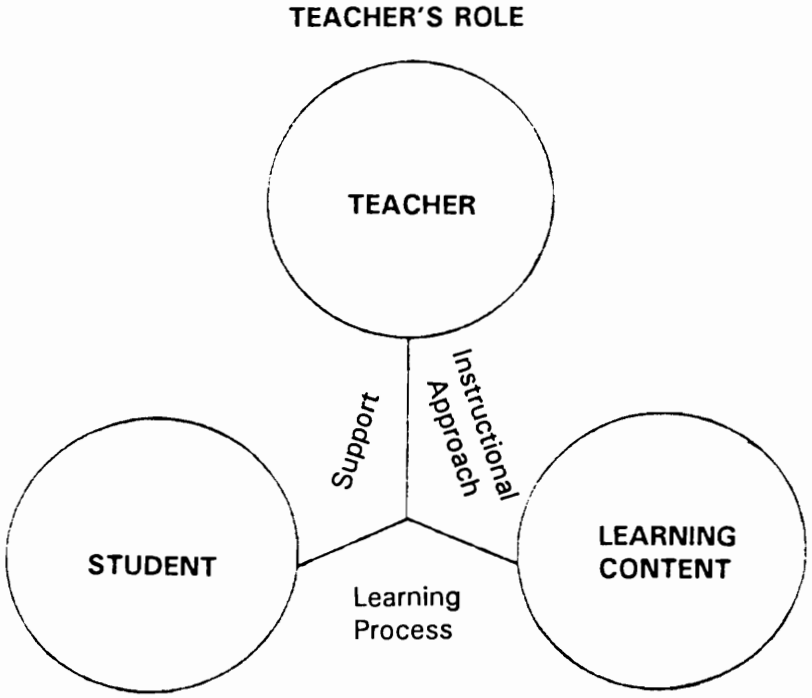
The teacher should devise and organize activities that are concrete, adapted to the students' abilities and interests, and directly related to their life experiences. In addition, these activities should help develop in the students a concern for health and safety and for the environment.

Some may feel that the teacher's role has been profoundly changed. Teachers should not provide the answer or impose an approach to a problem, but rather prepare learning situations with the students in mind, guide them through the learning process, support them, and help them take stock of what they have done and of what they have learned. The teacher is, in a way, the catalyst in this new approach to physics education.

Particular attention should be paid to the number of research and laboratory reports assigned as class work or as homework. Too many written assignments could affect the quality of the students' work and cause them to lose interest in science. It will also mean that teachers will have to spend more time correcting papers.

In short, this program advocates an interactive learning approach. The teacher is called upon to provide students with the best opportunity to experience the real world of science, to

to encourage them to work together and to help them discover how science relates to history, technology, social concerns, and environmental issues.



2.6 Student's Role (Learning Approach)

The students will learn to take responsibility for their own education by:

- participating in all proposed activities
- contributing to group experiments
- developing hypotheses and testing them
- doing experiments using their own procedures or suggested procedures
- proposing models and theories
- sharing their conclusions
- assessing the impact of their actions and those of scientists and technologists on the environment and the quality of life
- formulating generalizations and laws
- comparing their results with those of other students and of scientists
- communicating their results in a variety of ways (e.g. written reports, oral presentations, exhibits)

In this program, students will be given the opportunity to apply what they have learned (i.e. knowledge, skills and attitudes) by carrying out a research project that simulates the work of a physicist.

2.7 Guiding Principles

The three guiding principles that reflect the results of the needs analysis and the foundations and orientations of this program are summarized in the following diagram.

Sociological Foundations

An instructional method that focuses on the integration of learning.

(Relationships between science, technology and society)

Pedagogical Foundations

An instructional method designed to help students use the scientific method to explore phenomena in the environment

(Experimental method)

STUDENTS
"architects" of their own education:

- skills
- knowledge
- attitudes

Epistemological Foundations

An instructional method based on the concept of constructing knowledge

(Constructivism)

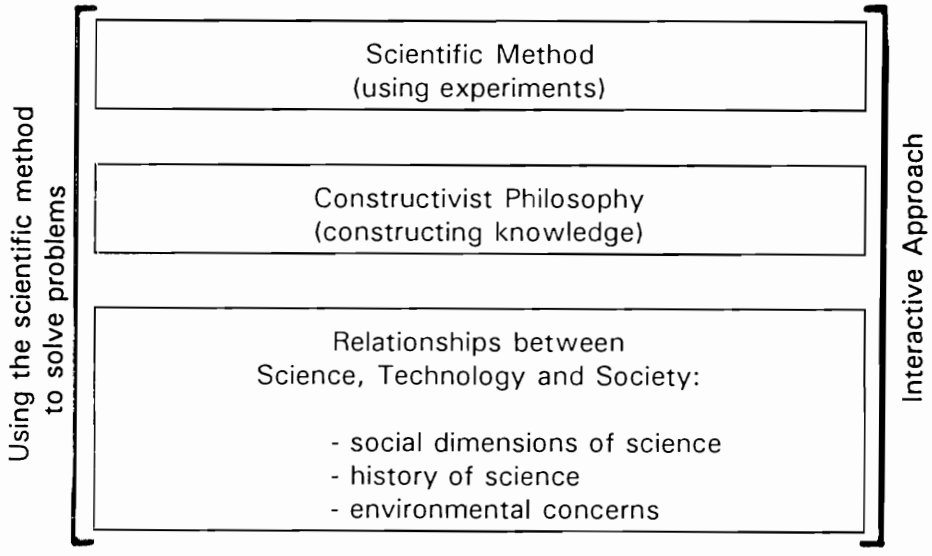
2.8 Summary of the Orientations of the Program

This program emphasizes the scientific method, laboratory work and group work. Its goal is to provide students with a solid fundamental education and an excellent background in science.

The basic philosophy promoted in this program is the acquisition of knowledge using constructivist methods. Scientific knowledge is not carved in stone, but rather modified through research and experiments aimed at developing a greater understanding of phenomena in the environment on the basis of what is already known. Students are therefore encouraged to construct their own knowledge by conducting research and experiments on the basis of what they already know, keeping in mind that their results may oblige them to change their view of a particular phenomenon.

This program calls for an interactive learning approach in which the teacher's role is to guide the students as they use the scientific method to solve problems. This new approach to teaching physics enables students to become familiar with the relationships between physics, technology and society and to learn how to explain and examine how physics relates to the environment. As a result, students learn to appreciate the strengths and limitations of scientific inquiry and ultimately gain a comprehensive understanding of the role of physics in modern society.

ORIENTATIONS



The teacher **guides** the students as they use the **scientific method** to **solve** problems.

3. FOCUS OF LEARNING

3.1 Global Objective

Although this program is chiefly designed for students who plan to study science at the post-secondary level, it is not aimed at producing specialists. Its main objectives are to foster the students' interest in physics, to help them adapt to the constant changes brought about by science, and to prepare them for a career in science or technology. It enables the students to continue to structure the concepts of matter and energy, to become aware of environmental issues and to study the relationships between science, technology and society by providing them with the opportunity to investigate natural phenomena and technology related to physics. In this way, they will construct the knowledge, intellectual and technical skills and attitudes that will help them to become citizens who are well equipped to participate in the decision-making process that will affect the future of humanity.

Like Physical Sciences 416-436, **Physics 534 is designed above all to make students aware of the fundamentals of science.**

3.2 Goals

In order to achieve the global objective of this program, students should develop the knowledge, skills and attitudes listed below.

KNOWLEDGE

This program helps students to:

- develop a broader understanding of concepts studied in Secondary IV
- structure the concepts, laws and principles that enable them to understand and explain natural phenomena and technology related to physics
- become familiar with the nature of physics, its capabilities and its limitations
- understand the limitations of measurements and techniques

. understand the relationships between science, technology and society
. develop communication skills

SKILLS:

This program helps the students to:

. refine the skills developed in Secondary IV
. develop the skills required to be scientists
. acquire the ability to think "scientifically"
. develop problem-solving abilities
. learn how to work methodically and safely when doing scientific research
. learn how to develop models
. learn how to work in a team

ATTITUDES

This program helps students to:

. further develop the attitudes promoted in Secondary IV
. learn how to objectively analyze physics and the work of physicists
. develop "scientific" attitudes
. develop ethical concerns regarding social and environmental issues
. develop an interest in scientific work and leisure-time activities related to physics.

3.3 Learning Content and Integrating Themes

The learning content focuses on the following elements:

- certain concepts relating to physics and that take into account issues that concern individuals, society, the economy, the environment and technology;

- work and research methods that physicists use to discover and understand the behaviour of matter and the role of energy and to apply this knowledge in different fields;

- attitudes that will help students prepare for a career and for life in society

These elements have been integrated into the objectives of this program. The concepts are related to mechanics, energy and the nature of light, while the development of skills and attitudes is achieved through learning activities that employ carefully chosen teaching strategies and instructional materials.

The students become familiar with a multitude of natural and technological phenomena, some of which may become major areas of interest and lead to further investigations. This type of inquiry is central to this program and gives students the opportunity not only to continue developing their knowledge, skills and attitudes, but also to examine the relationships among science, technology and society.

3.4 Objectives of the Program

The orientations of the program are integrated into the objectives and the learning activities of the modules. Since little has been written on how to design programs that reflect the constructivist view of science, this approach may seem somewhat awkward at first. What is important is to respect the philosophy of the program and to help students construct the learning content in accordance with that philosophy.

3.5 General Objectives

After field-testing the experimental version of this program and receiving feedback from experts, the authors selected three modules for Physics 534. Two of these modules enable the students to construct knowledge, skills and attitudes by studying a variety of concepts, and the third module gives them the opportunity to conduct research that requires them to integrate the knowledge, skills and attitudes they have developed. The general objective of each module reflects the orientations of the program.

3.6 Specific Objectives

The general objective of each module is described in greater detail by means of terminal objectives. The order in which the terminal objectives are presented can be changed to reflect the students' interests, abilities and progress, or the teacher's personal style of teaching. The terminal objectives are formulated so as to help students construct the related content (i.e knowledge, skills and attitudes) according to the orientations of the program.

Each terminal objective is divided into intermediate objectives that are also presented in a certain sequence which can be adapted to the students' needs or to the situation in a particular school. Suggested learning activities and a proposed teaching plan define the scope of these intermediate objectives.

The terminal objectives (i.e. those printed in bold type in the modules) are compulsory and will be evaluated by the Ministère. This evaluation should take into account the orientations of the program as emphasized in the intermediate objectives, the learning activities and related content and should not extend beyond the scope of these three items. Intermediate objectives preceded by two asterisks are suggested enrichment activities and should be evaluated by means of locally-prepared examinations.

The general and terminal objectives of each module are listed starting on p. 23.

OBJECTIVES OF THE PROGRAM

MODULE 1: THE NATURE OF LIGHT

GENERAL OBJECTIVE

To investigate, by means of the scientific method, the phenomenon of light in the environment, in order to discover its main properties and to understand how optical devices work.

TERMINAL OBJECTIVES

THE STUDENTS WILL LEARN HOW TO:

1. Show how light is transmitted, by referring to light phenomena they have observed in their environment or in a laboratory.

2. Analyze the behaviour of light reflected from mirrors of different shapes, by referring to observations of light phenomena in their environment and to the results of laboratory experiments they have conducted.

3. Analyze the behaviour of light refracted by different substances, by referring to their observations of light phenomena in their environment and to laboratory experiments they have conducted.

4. Analyze the characteristics of lenses, on the basis of what they have learned about the behaviour of light while doing scientific work.

5. Analyze the characteristics of images formed by optical devices, on the basis of their experimental results and using the skills and knowledge acquired while studying the reflection and refraction of light.

6. Make a study showing how the development of knowledge in the field of optics has affected other branches of science, technology, society and the environment.

MODULE 2: OPTICAL DEVICES

GENERAL OBJECTIVE

To help students broaden their scientific knowledge by having them construct an optical device that will enable them to apply what they have learned and to explore different technologies.

TERMINAL OBJECTIVE

THE STUDENTS WILL LEARN HOW TO:

1. Present the results of a quantitative study that involves designing an optical measuring device in order to examine a mechanical phenomenon of their choice, using correct language.

MODULE 3: MECHANICS

GENERAL OBJECTIVE

To investigate the motion of objects in the environment, to discover the causes of motion and to understand the mechanical phenomena associated with it, using the scientific method.

TERMINAL OBJECTIVES

THE STUDENTS WILL LEARN HOW TO:

1. Describe the motion of objects or organisms that they have explored with their senses.
2. Analyze the effects of forces that they have felt or which act on objects in their environment.
3. Describe the movement of objects, using the physical magnitudes they analyzed during experiments.
4. Analyze the rectilinear motion of objects to which forces are applied, on the basis of the results obtained in laboratory experiments.
5. Select a simple machine to perform a task, on the basis of specific qualities they have analyzed in the laboratory.
6. Demonstrate that work is produced with every transformation of mechanical energy.
7. Identify the consequences for science, technology, society and the environment of developing and using our knowledge of motion, by doing an impact study.

3.7 Learning Activities

A list of structured learning activities is provided for each intermediate objective. These activities are suggestions that can be used by the teacher to help the students achieve the intermediate objective. The teacher may propose other learning activities provided they are consistent with the orientations of the program. They should also reflect the students' interests, abilities and learning styles and enable them to construct knowledge and solve problems by applying what they have learned as they investigate their environment.

Themes or topics to be reviewed are listed at the beginning of the learning activities if they are deemed appropriate to the objective. This information consists of certain skills or knowledge that the students should normally have acquired in one or more previous courses. This material should be reviewed at the most appropriate point in the learning sequence.

3.8 Suggested Teaching Plan

Elements that teachers may want to consider when planning their instructional approach are suggested for each intermediate objective.

PREREQUISITES

This indicates the objectives in this program that are prerequisites for a particular intermediate objective.

In addition, review references at the beginning of the learning activities pertain to knowledge that students have normally acquired in previous courses. This is to remind teachers that they should help students construct new learning content on the basis of material already covered.

RELATED CONTENT

The related content for each intermediate objective consists of the skill, knowledge, and attitude that students are expected to develop. These items are simply suggestions that will help teachers determine and plan their instructional approach and methods of evaluation.

Appendix I presents a list of skills and attitudes emphasized in this program. The alphanumeric code in parentheses refers to the taxonomy in Appendix II.

TEACHING STRATEGY

This indicates the various teaching/learning techniques that can be used individually, sequentially or concurrently.

The techniques selected and the order in which they are used constitute a teaching strategy that reflects the philosophy of the program. Regardless of the strategy selected, the teacher should ensure that the students play an active role in the learning process.

DURATION

This indicates the time it should take to help students attain an intermediate objective.

The terms "homework" and "free time" refer to the time that students must devote to their studies (e.g. reading assignments, development of experimental procedures, experiments, research, written reports) outside school hours.

EVALUATION

This indicates areas that the teacher could focus on for formative evaluation to determine whether the students have attained the intermediate objective.

MATERIALS

This indicates the instruments, materials and substances that should be made available to the students or used during demonstrations. The materials used will depend on the suggested learning activities.

Students may also be asked to select, bring or even construct the required materials.

First-aid supplies and safety equipment that should normally be available at all times are not listed under this heading. The teacher must ensure that these supplies and this equipment are available and used by students when necessary.

SAFETY MEASURES

This concerns information on health and safety measures and environmental protection. Individual protective equipment should be selected in accordance with this information.

See the following documents for details: *Health and Safety in the Natural Science Laboratory* and *Guide for Handling and Disposing of Hazardous Substances in the Schools* (full references listed in Chapter 9, **RELATED DOCUMENTS**).

SUGGESTED REFERENCES

This is a list of codes for books, magazine articles, audiovisual materials and educational software pertaining to the particular objective. Some of these references are for the teacher's use; others are suitable for students. The full reference corresponding to each alphanumeric code is indicated in Appendix III.

TEACHERS NOTES

Drawing on their own experience, teachers can use this section to add information on references, teaching plans or other matters. They can also make notes on anything that would be useful to future teachers.

3.9 Students' Research Projects

Students are required to complete at least one research project of their choice during the school year. A list of projects that may be of interest to the students as well as a procedure for doing this work are contained in Module 2. Students can carry out this project individually or in small groups and it can be done as class work, homework, within extracurricular activities, or concurrently with Module 3.

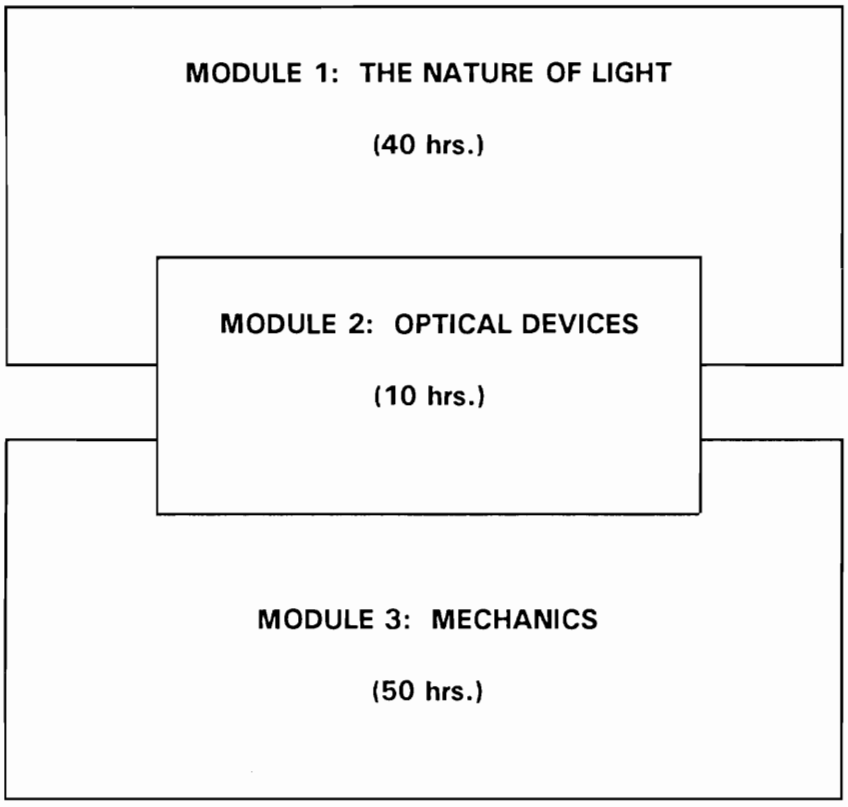
Teachers are strongly encouraged to have students present their research results in class or at a science fair. This will prove to be a valuable educational exercise both for the students giving these presentations and for their audience.

4. STRUCTURE OF THE PROGRAM AND LEARNING CONTENT

This program-guide for *Physics 534: The Discovery of Matter and Energy* contains three compulsory modules the second of which requires the students to carry out a research project. The material in each module is presented as a sequence of learning activities aimed at providing students with meaningful learning situations that reflect the orientations of the program.

4.1 Relationship Among the Modules

The following diagram illustrates the relationship among the three modules:



Modules 1 and 3 propose enrichment objectives for students who attain the compulsory objectives in less than the 100 hours normally allotted to the required material. Teachers should feel free to cover the suggested enrichment objectives, develop other enrichment objectives that reflect their students' specific interests, or help their students explore new topics that may be of interest to them. Preparing students for cégep is a commendable goal, however, it is important to maintain their interest in the sciences.

4.2 Module 1: The Nature of Light

Over the last few decades, investigating optical phenomena has become a modern technological challenge. The invention of the laser in the 1950s captured the interest of scientists, industry and the medical field. In addition, every area of human activity has felt the influence of fibre-optic technology.

The ability to understand methods of investigating the nature of light is a valuable asset that will enable both future professional scientists and ordinary citizens to develop a more critical attitude towards technological developments.

4.3 Module 2: Optical Devices

Designing, constructing and using optical devices to measure phenomena such as forces, masses, energy transformations and the motion of objects or organisms calls for imagination and creativity. This program serves as a training ground for the inventive scientists and technicians of tomorrow.

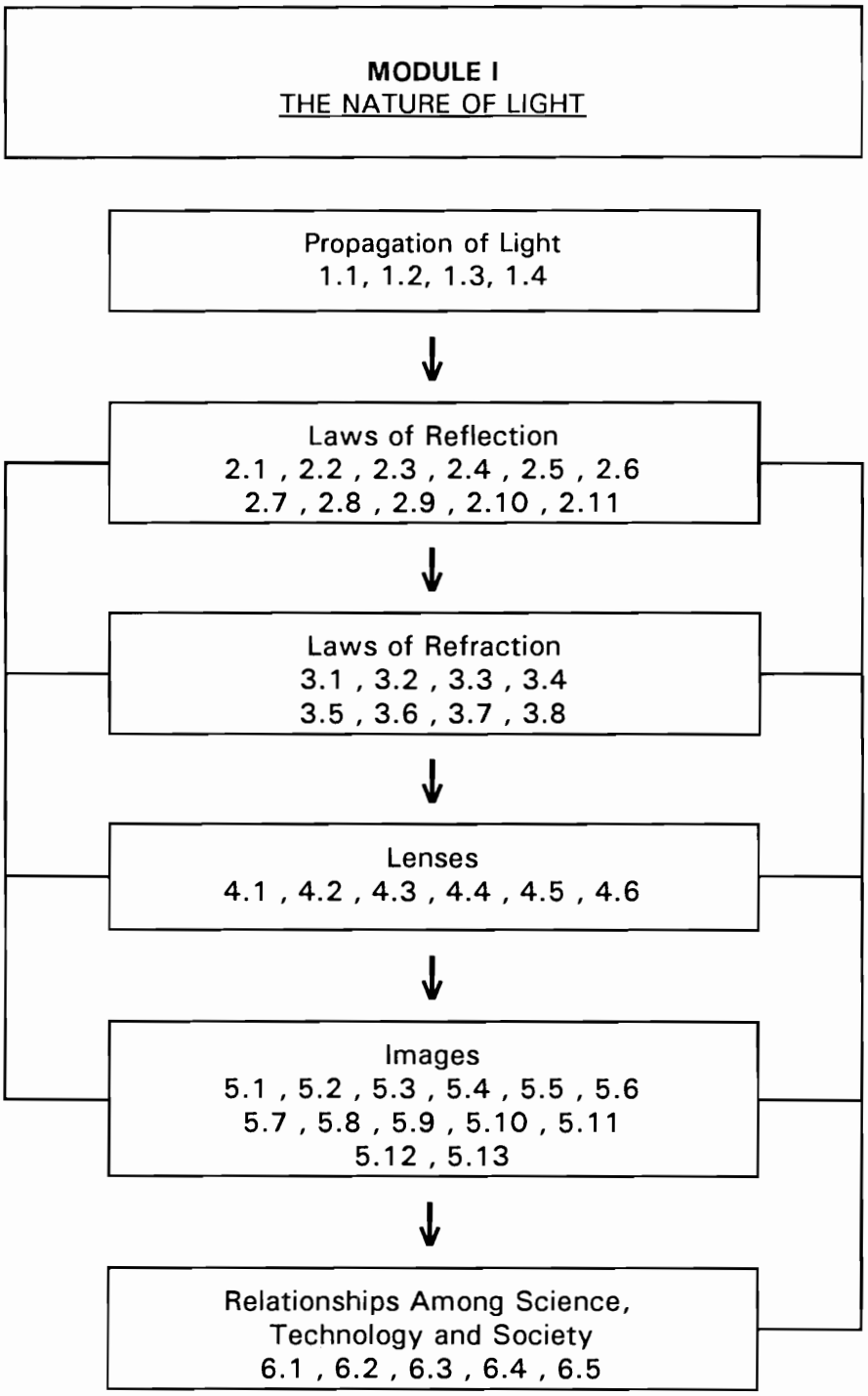
4.4 Module 3: Mechanics

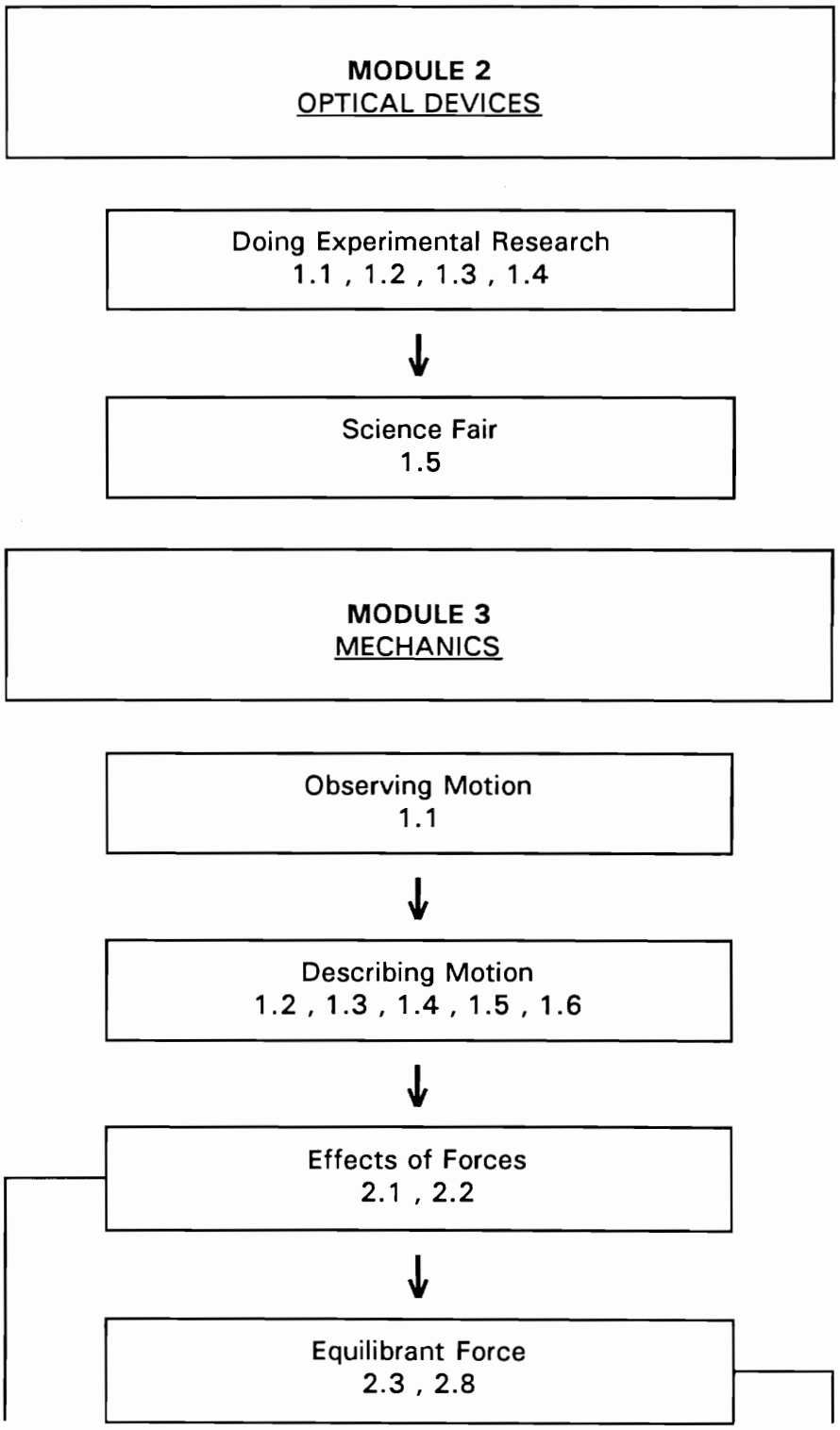
Mechanics has been a focal point of scientific research since the beginning of time.

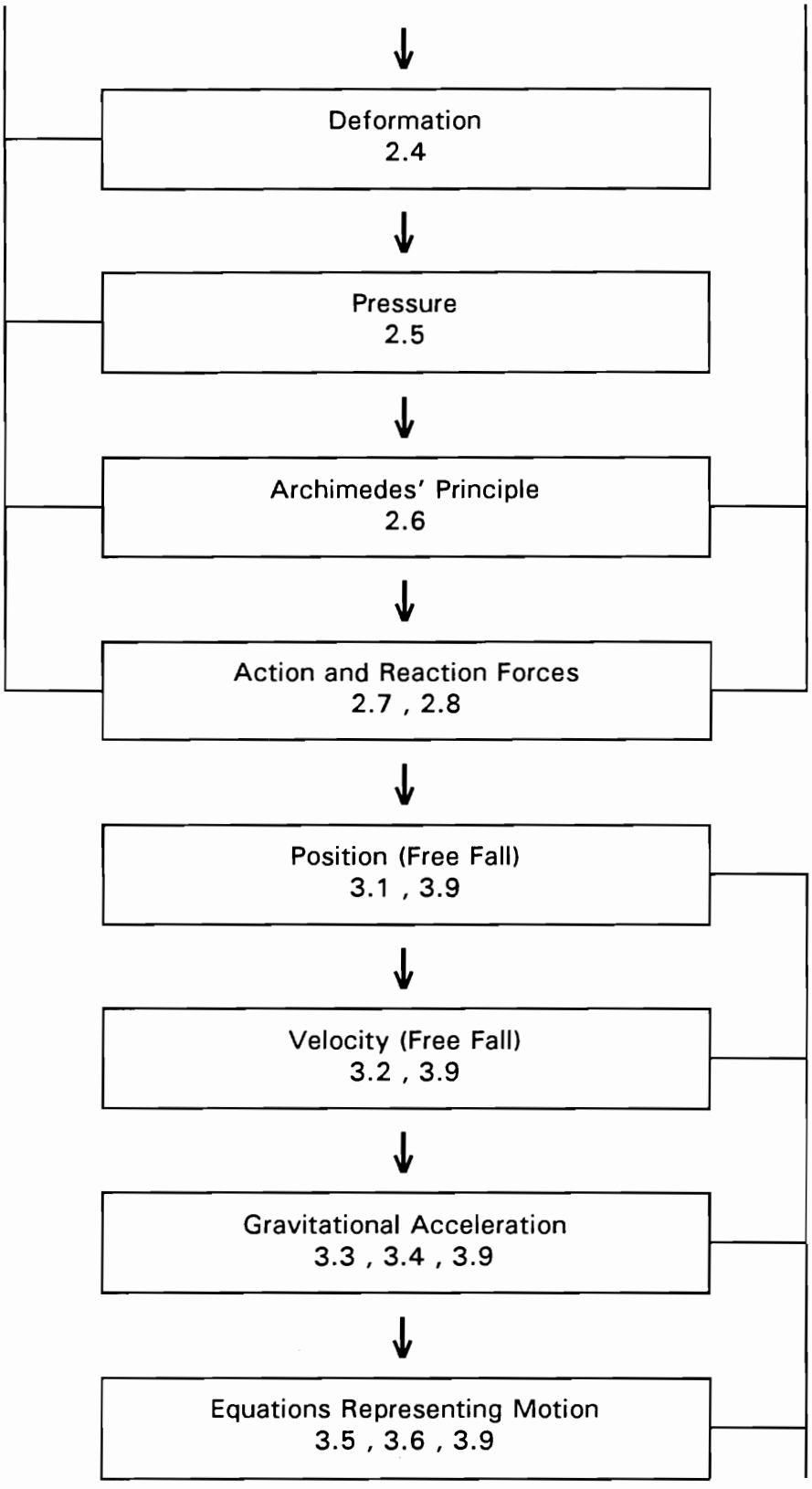
The empirical approach emphasized in this program will give students the opportunity to examine mechanical phenomena and feel the effects of various forces (e.g. acceleration, thrust, pressure, heat energy), observe changes in the motion of objects, and relate their own

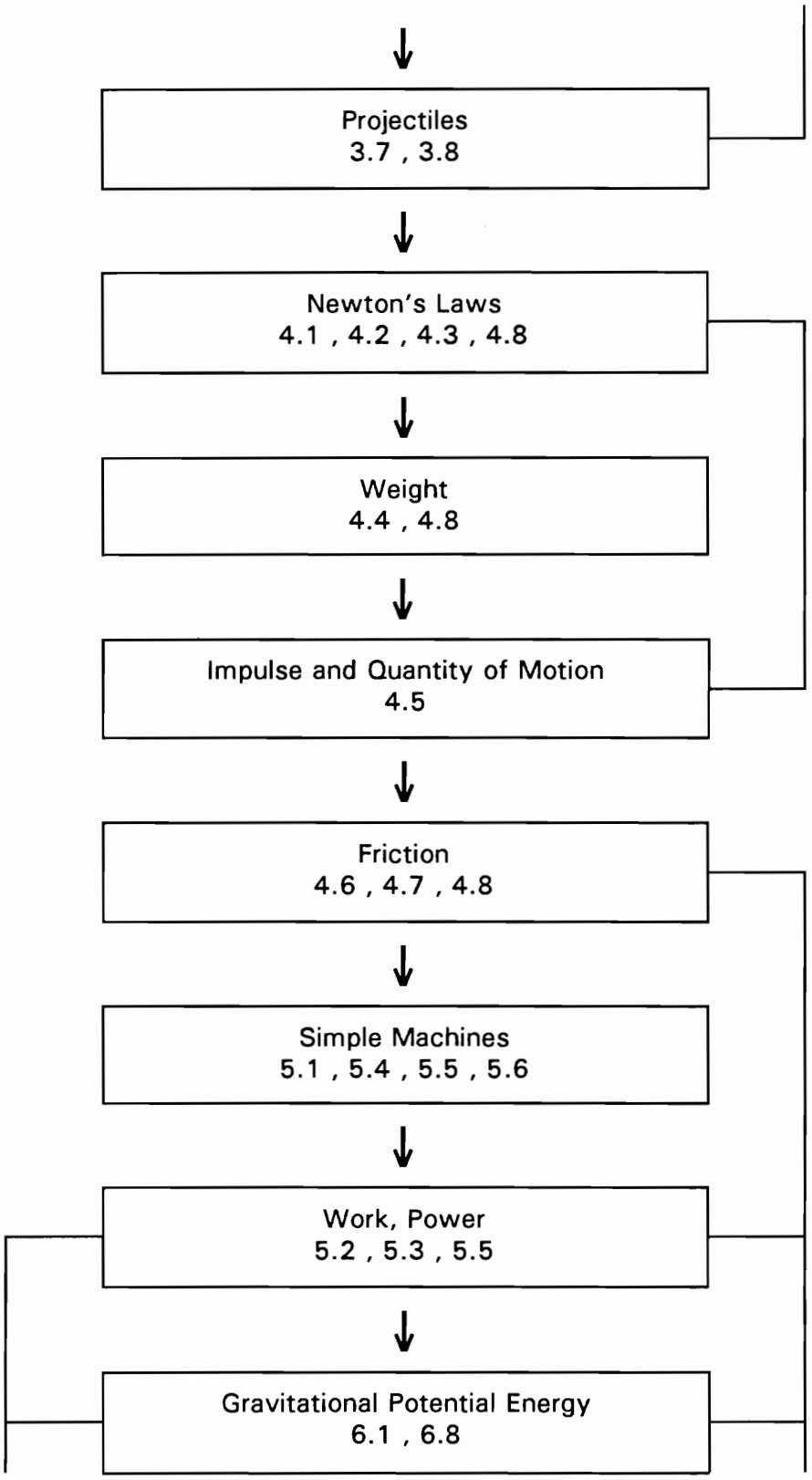
experiences to what they have observed in the laboratory. As scientists, technicians and engineers, they will have to refine and use the very models that they will begin to construct in this module.

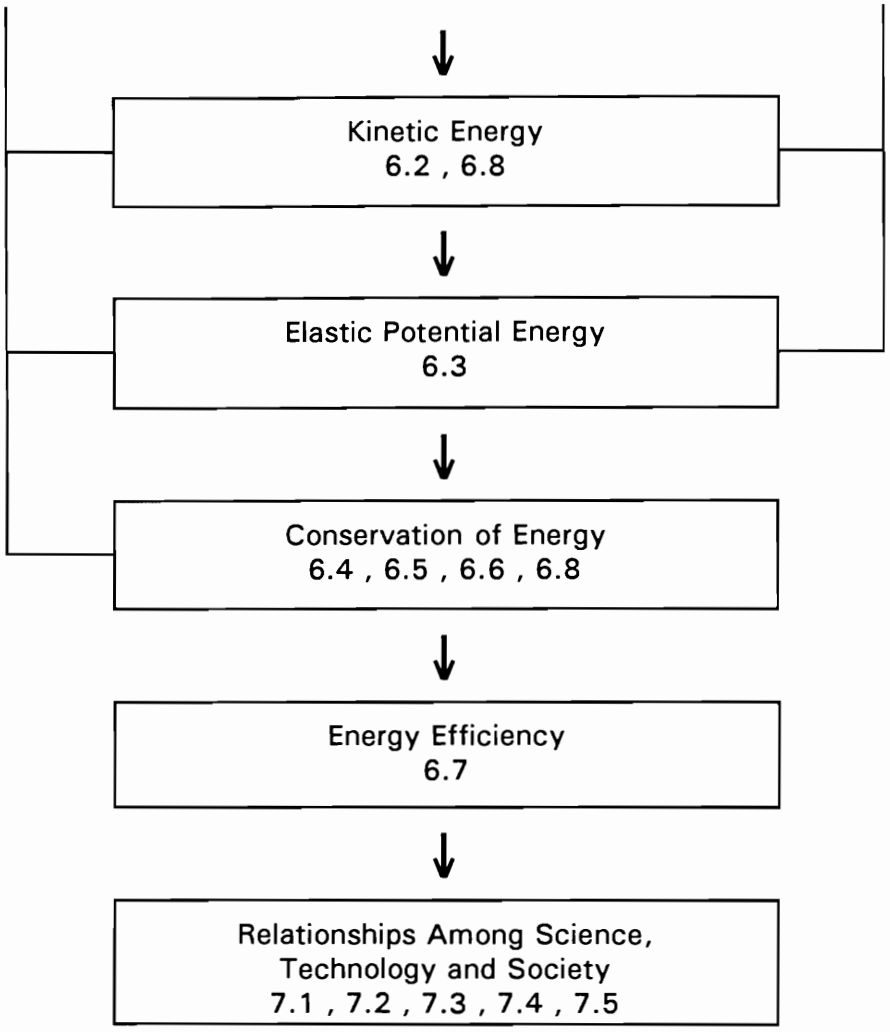
5. ORGANIZATION OF TOPICS COVERED IN THE PROGRAM




MODULE 2
OPTICAL DEVICES
Doing Experimental Research
1.1 , 1.2 , 1.3 , 1.4
Science Fair
1.5
MODULE 3
MECHANICS
Observing Motion
1.1
Describing Motion
1.2 , 1.3 , 1.4 , 1.5 , 1.6
Effects of Forces
2.1 , 2.2
Equilibrant Force
2.3 , 2.8


Deformation
2.4
Pressure
2.5
Archimedes' Principle
2.6
Action and Reaction Forces
2.7 , 2.8
Position (Free Fall)
3.1 , 3.9
Velocity (Free Fall)
3.2 , 3.9
Gravitational Acceleration
3.3 , 3.4 , 3.9
Equations Representing Motion
3.5 , 3.6 , 3.9


Projectiles
3.7 , 3.8
Newton's Laws
4.1 , 4.2 , 4.3 , 4.8
Weight
4.4 , 4.8
Impulse and Quantity of Motion
4.5
Friction
4.6 , 4.7 , 4.8
Simple Machines
5.1 , 5.4 , 5.5 , 5.6
Work, Power
5.2 , 5.3 , 5.5
Gravitational Potential Energy
6.1 , 6.8


Kinetic Energy
6.2 , 6.8
Elastic Potential Energy
6.3
Conservation of Energy
6.4 , 6.5 , 6.6 , 6.8
Energy Efficiency
6.7
Relationships Among Science,
Technology and Society
7.1 , 7.2 , 7.3 , 7.4 , 7.5

6. PROGRAM-GUIDE

MODULE 1

THE NATURE OF LIGHT

MODULE OBJECTIVE: To investigate, by means of the scientific method, the phenomenon of light in the environment, in order to discover its main properties and to understand how optical devices work.

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1 **Show how light is transmitted, by referring to light phenomena they have observed in their environment or in a laboratory.**

1.1 Identify light phenomena they have observed in their environment or in a laboratory.

PREREQUISITES:

RELATED CONTENT:

—	**SKILL:**	Observing. (B-2)
—	**KNOWLEDGE:**	Natural and "artificial" light phenomena, historical developments. (A-1)
—	**ATTITUDE:**	Intellectual curiosity. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, presentation, demonstration, group work.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' descriptions.
D.	**MATERIALS:**	Light sources (incandescent, fluorescent), mirrors, 500-mL beaker, water, milk, cream, microscope, overhead projector, lampblack, prism, ultraviolet light source, Van de Graaff generator (lightning), spectrum tubes, diffraction grating, films, videos, slides, reference material.
E.	**SAFETY MEASURES:**	Possible emission of ionizing radiation, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-56, AV-57, AV-58, AV-59, AV-60, AV-67, AV-69
B-8, B-22
M-2, M-21, M-47, M-53

LEARNING ACTIVITIES

THE STUDENTS:

1.1.1 List light phenomena in their environment.

1.1.2 Observe demonstrations of different interactions of matter and light (e.g. incandescence, fluorescence, phosphorescence, reflection, refraction, diffusion, dispersion, diffraction, absorption, interferences).

1.1.3 Relate phenomena they have observed in their environment to phenomena observed in the above-mentioned demonstrations.

1.1.4 Show that humanity's fascination with light phenomena dates back to prehistoric times, after doing background reading on the subject.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE **STUDENTS WILL LEARN HOW TO:**

1.2 Describe the behaviour of light beams observed in a laboratory, using diagrams.

PREREQUISITES:

1.1

RELATED CONTENT:

–	**SKILL:**	Observing. (B-2)
–	**KNOWLEDGE:**	Light beam, pencil of light, light ray, extended source of light, point source of light, ray box, source of laser light, historical developments. (A-2)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, demonstration, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' understanding of ray box.
D.	**MATERIALS:**	Light sources, perforated screens, screen, object, software, microcomputer, ruler, pinhole camera, source of laser light.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-69, AV-73
B-26
M-14, M-21

LEARNING ACTIVITIES

THE STUDENTS:

1.2.1 Formulate a hypothesis describing the relative position of a light source and a perforated screen if an object is completely illuminated, using a diagram.

1.2.2 Compare one another's hypotheses and select one for further study.

1.2.3 Test the selected hypothesis by conducting an experiment.

1.2.4 Correct their diagrams, if necessary.

1.2.5 Propose a diagram of a pencil of light.

1.2.6 Compare one another's proposals and select one or more for further study.

1.2.7 Verify the selected proposal(s) by conducting an experiment.

1.2.8 Compare their conceptions of a light ray with the generally accepted definition.

1.2.9 Distinguish the behaviour of laser light from that of other light sources, after observing a demonstration.

1.2.10 Learn about Giambattista Della Porta's work with the camera obscura in the 16th century.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.3 Illustrate the umbra and penumbra that they have created in the laboratory or observed in the environment, using diagrams.

PREREQUISITES:

1.2

RELATED CONTENT:

–	**SKILL:**	Generalizing. (B-2)
–	**KNOWLEDGE:**	Umbra, penumbra, solar eclipse, lunar eclipse, lunar phases, source-obstacle-screen relationship, rectilinear propagation of light, technical objects with a viewfinder, pinhole camera, historical developments. (A-10)
–	**ATTITUDE:**	Fascination with science. (H-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' ability to develop a procedure.
D.	**MATERIALS:**	Light sources, screens, opaque objects, cardboard, tracing paper, reference material.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-58
B-29, B-35
M-13, M-14, M-26

LEARNING ACTIVITIES

THE STUDENTS:

1.3.1 Propose a method of producing shadows on a screen.

1.3.2 Develop a procedure for testing their proposed methods.

1.3.3 Conduct a laboratory experiment.

1.3.4 Draw a scale diagram of the apparatus used in their experiments.

1.3.5 Deduce the following from the diagram drawn in 1.3.4: the phenomenon of rectilinear propagation is responsible for the formation of the shadow.

1.3.6 Connect the formation of the umbra and penumbra with the relationships among the following variables: size of the source, size of the object, and the relative distances between the source, the object, and the screen.

1.3.7 Propose descriptions of the following phenomena: partial eclipse of the sun, total eclipse of the sun, partial eclipse of the moon, total eclipse of the moon.

1.3.8 Compare one another's descriptions.

1.3.9 Identify phenomena in their environment that can be observed solely because of the rectilinear propagation of light.

1.3.10 Discuss how the principle of rectilinear propagation of light is applied in the use and manufacture of technical objects (e.g. sight on a gun, theodolite, pinhole camera.)

1.3.11 Learn about Thales' work on the prediction of eclipses.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 1.4 Determine a relationship between the area illuminated on a surface and the distance between the light source and that surface, on the basis of their experimental results.

PREREQUISITES:

1.3

RELATED CONTENT:

—	**SKILL:**	Interpreting data. (E-2)
—	**KNOWLEDGE:**	Relationship between the area illuminated on a surface and the distance between the source and that surface, nature of the second-degree curve representing the inverse square law of illumination, technological applications. (A-8)
—	**ATTITUDE:**	Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, class discussion.

B.	**DURATION:**	100 minutes.
C.	**EVALUATION:**	Students' ability to interpret data.
D.	**MATERIALS:**	Point source of light, cardboard, ruler, photometer (optional), reference material.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

B-1, B-14
CS-7, CS-15, CS-16, CS-18
M-24

LEARNING ACTIVITIES

THE STUDENTS:

1.4.1 Set up an apparatus consisting of a point source of light that illuminates a screen, on the basis of a diagram.

1.4.2 Formulate a hypothesis to explain why the area illuminated on the screen changes as that surface is moved farther away from the light source.

1.4.3 Compare one another's hypotheses and select one for further study.

1.4.4 Draw a diagram representing the selected hypothesis.

1.4.5 Relate the change in the area illuminated on the screen to the concept of rectilinear propagation of light.

1.4.6 Draw a graph showing how the area illuminated on the screen varies with the distance between the light source and that surface, after conducting an experiment in accordance with the suggested procedure.

1.4.7 Propose a mathematical relationship between the area illuminated on the screen and the distance between the light source and that surface, on the basis of their graphs.

1.4.8 Compare one another's proposals.

1.4.9 Find technological applications of the mathematical relationship they have formulated.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2 **Analyze the behaviour of light reflected from mirrors of different shapes, by referring to their observations of light phenomena in their environment and to the results of laboratory experiments they have conducted.**

2.1 Identify examples of reflected light in their environment.

PREREQUISITES:

1.3

RELATED CONTENT:

–	**SKILL:**	Observing. (B-1)
–	**KNOWLEDGE:**	Diffuse reflection, specular reflection, visual perception of objects, historical developments. (A-3)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, demonstration, class discussion, individual work.

B.	**DURATION:**	50 minutes in class + homework.
C.	**EVALUATION:**	Students' interpretations.
D.	**MATERIALS:**	Opaque objects, mirrors, chalk dust, source of smoke, source of laser light, ray box, reference material.
E.	**SAFETY MEASURES:**	Precautions in handling the laser.

SUGGESTED REFERENCES:

AV-23, AV-24, AV-25, AV-26, AV-27, AV-28, AV-56
B-37
CS-42
M-14, M-48

LEARNING ACTIVITIES

THE STUDENTS:

2.1.1 Identify examples of reflected light that occur in the environment and in everyday life.

2.1.2 Illustrate the situations identified above, using diagrams.

2.1.3 Distinguish between diffuse and specular reflection, after observing a demonstration.

2.1.4 Compare the Platonic theory that visual rays travel from the eye to the object with the atomist theory that they travel from the object to the eye (Lucretius, 1rst Century B.C.).

2.1.5 Relate people's visual perception of objects to reflected light phenomena.

2.1.6 Describe how Alhazen's (Ibn al-Haytham, 11th century) theory of vision influenced scientists of his time.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.2 Demonstrate the operation of a device containing one or more mirrors, using diagrams.

PREREQUISITES:

1.2, 1.3, 2.1

RELATED CONTENT:

–	**SKILL:**	Formulating a hypothesis (predicting). (C-2)
–	**KNOWLEDGE:**	Devices containing one or more mirrors (e.g. sextant, flashing light, projector, stroboscope, telescope, periscope, rangefinder), historical developments. (A-1)
–	**ATTITUDE:**	Intellectual curiosity. (I-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, laboratory work, group work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Student's ability to formulate hypotheses.
D.	**MATERIALS:**	Devices containing mirrors (e.g. sextant, flashing light, stroboscope, telescope, periscope), ruler, protractor.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-58
B-28
M-49

LEARNING ACTIVITIES

THE STUDENTS:

2.2.1 Identify activities in which mirrors are most often used.

2.2.2 List devices that contain one or more mirrors.

2.2.3 Become aware of other devices that function with one or more mirrors.

2.2.4 Draw a diagram of a given device.

2.2.5 Identify on a diagram the optical components of that device.

2.2.6 Formulate a hypothesis regarding the behaviour of light when this device is used, on the basis of a ray diagram.

2.2.7 Compare one another's hypotheses.

2.2.8 Describe the behaviour of light reflected from a pivoting mirror, by means of a mathematical relationship.

2.2.9 Compare one another's descriptions.

2.2.10 Describe how the use of mirrors has led to the development of new technologies throughout history, after consulting reference materials.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 2.3 Determine the position of an object, using a device that contains a system of plane mirrors.

PREREQUISITES:

2.2

RELATED CONTENT:

–	**SKILL:**	Measuring. (B-3)
–	**KNOWLEDGE:**	Measurement techniques associated with the use of a device containing plane mirrors. (A-7)
–	**ATTITUDE:**	Willingness to compare ideas. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' measurements.
D.	**MATERIALS:**	Measuring instrument containing a system of plane mirrors (e.g. sextant, rangefinder).
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

2.3.1 Observe a given object by means of a device used in 2.2.

2.3.2 Measure one or more of the coordinates for that object.

2.3.3 Compare one another's measurements.

2.3.4 Correct the diagrams drawn in 2.2, if necessary.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.4 Describe the behaviour of light reflected from a plane mirror, after conducting experiments.

PREREQUISITES:

1.2, 1.3

RELATED CONTENT:

- **SKILL:** Generalizing. (B-2)
- **KNOWLEDGE:** Law of reflection of light, historical developments. (A-8)
- **ATTITUDE:** Objectivity. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, class discussion.

B. DURATION: 50 minutes.

C. EVALUATION: Student's understanding of the law of reflection of light.

D. MATERIALS: Plane mirror, ray box, pins, protractor, Bristol board, source of laser light, reference material.

E. SAFETY MEASURES: Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-57
B-30
CS-14, CS-20

LEARNING ACTIVITIES

THE STUDENTS:

2.4.1 Observe objects, using a plane mirror.

2.4.2 Predict the path followed by pencils of light reflected from a plane mirror, using a diagram.

2.4.3 Compare one another's predictions and select one for further study.

2.4.4 Verify the selected prediction by conducting an experiment.

2.4.5 Propose a law of reflection of light, on the basis of the results of their experiments.

2.4.6 Compare one another's proposals.

2.4.7 Compare their proposals with the one Hero of Alexandria (1st century) outlined in the *Catoptric*.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.5 Determine the field of vision of an observer facing a mirror, after conducting experiments.

PREREQUISITES:

2.4

RELATED CONTENT:

—	**SKILL:**	Observing. (B-2)
—	**KNOWLEDGE:**	Field of vision of an observer facing a mirror, normal, use of mirrors. (A-10)
—	**ATTITUDE:**	Intellectual curiosity. (H-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, field trip, class discussion.

B.	**DURATION:**	100 minutes.
C.	**EVALUATION:**	Student's diagram of the visual field.
D.	**MATERIALS:**	Ray box, protractor, ruler, pins, Bristol board, plane mirror, convex mirror, concave mirror.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

M-21, M-48

LEARNING ACTIVITIES

THE STUDENTS:

2.5.1 Identify everyday situations in which mirrors are used.

2.5.2 Observe objects placed in their field of vision, using a mirror.

2.5.3 Predict their field of vision, using a diagram.

2.5.4 Verify their predictions by conducting an experiment.

2.5.5 Propose ways of changing their field of vision.

2.5.6 Verify their proposals by conducting an experiment.

2.5.7 Compare one another's proposals.

2.5.8 Become aware of why the normal is useful for drawing angles of incidence and angles of reflection to study curved mirrors.

2.5.9 Discuss the field of vision of a person facing a mirror.

2.5.10 Discuss ways of using a mirror to observe someone without being seen by that person.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.6 Analyze the behaviour of light reflected from a curved mirror, after conducting experiments.

PREREQUISITES:

2.4

RELATED CONTENT:

–	**SKILL:**	Formulating a hypothesis. (C-2)
–	**KNOWLEDGE:**	Principal focus, secondary principal focus, radius of curvature, centre of curvature, principal axis, secondary axis, principal rays, spherical aberration. (A-2)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, class discussion.

B.	**DURATION:**	100 minutes.
C.	**EVALUATION:**	Students' analyses.
D.	**MATERIALS:**	Cylindrical concave mirrors, cylindrical convex mirrors, ray box, pins, protractor, Bristol board, curved mirrors to be used for demonstrations, source of laser light.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-23, AV-24, AV-25, AV-26, AV-27, AV-28
CS-12, CS-14, CS-25
M-21

LEARNING ACTIVITIES

THE STUDENTS:

2.6.1 Identify the principal points of a curved mirror (e.g. principal focus, secondary principal focus, vertex, radius of curvature, centre of curvature), after conducting an experiment according to the suggested procedure.

2.6.2 Predict the paths followed by incident rays that are parallel to the principal axis of a curved mirror, using diagrams.

2.6.3 Compare one another's predictions.

2.6.4 Verify these predictions by conducting an experiment.

2.6.5 Justify their predictions, on the basis of the knowledge they have acquired (concept of normal).

2.6.6 Demonstrate the advantages of using a parabolic mirror rather than a spherical mirror to make devices that contain a concave mirror (e.g. telescope, headlights, projector).

2.6.7 Relate the characteristics of concave mirrors to those of convex mirrors.

2.6.8 Describe how a metal can may cause a fire in the environment, using the knowledge they have acquired.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 2.7 Describe non-optical reflection that occurs naturally in the environment or that is produced through technological applications.

PREREQUISITES:

2.4, 2.6

RELATED CONTENT:

–	**SKILL:**	Generalizing. (F-2)
–	**KNOWLEDGE:**	Examples of non-optical reflection. (A-10)
–	**ATTITUDE:**	Fascination with science. (H-6)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, individual work, group work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' papers.
D.	**MATERIALS:**	Reference material.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-65, AV-66
M-33

LEARNING ACTIVITIES

THE STUDENTS:

2.7.1 List acoustical, mechanical, and radiocommunications objects as well as other technical objects whose operation is related to the phenomenon of reflection.

2.7.2 Propose a description of how these objects work.

2.7.3 Illustrate these proposals by means of a diagram.

2.7.4 Compare one another's diagrams.

2.7.5 Identify other physical phenomena caused by reflection, after consulting reference materials.

2.7.6 Write a short paper on one of the technical objects they have studied.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 2.8 Test his or her understanding of the behaviour of reflected light, using black boxes.

PREREQUISITES:

2.4

RELATED CONTENT:

–	**SKILL:**	Formulating a hypothesis. (C-2)
–	**KNOWLEDGE:**	Applications of the law of reflection. (A-8)
–	**ATTITUDE:**	Willingness to compare ideas. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, class discussion, educational game.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Logic of the students' reasoning.
D.	**MATERIALS:**	Set of mirrors, black boxes containing obstacles, light source, source of laser light.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

2.8.1 Place mirrors in a black box so that a beam of light can be transmitted from one point to another.

2.8.2 Predict the location of the mirrors placed in black boxes that other students have designed, using diagrams.

2.8.3 Verify their predictions by conducting an experiment.

2.8.4 Modify their diagrams, if necessary.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 2.9 Explain the use of different substances to manufacture mirrors.

PREREQUISITES:

2.6

RELATED CONTENT:

—	**SKILL:**	Generalizing. (F-1)
—	**KNOWLEDGE:**	Techniques for manufacturing mirrors, historical developments. (A-7)
—	**ATTITUDE:**	Critical attitude. (H-7)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, individual work, class discussion, field trips (visiting businesses and astronomy clubs).

B.	**DURATION:**	50 minutes in class + free time.
C.	**EVALUATION:**	Students' reasoning.
D.	**MATERIALS:**	Mirrors (e.g. metal, plastic, glass), reference materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

M-33, M-45, M-49

LEARNING ACTIVITIES

THE STUDENTS:

2.9.0 Review the concept of the properties of matter (Physical Sciences 416-436).

2.9.1 List substances used to make mirrors.

2.9.2 Identify the properties that justify the use of these substances.

2.9.3 Identify the advantages and disadvantages of using these substances.

2.9.4 Conclude that the relative position of these substances will affect the way in which light is reflected.

2.9.5 Describe technologies used to manufacture mirrors.

2.9.6 Discuss the advantages and disadvantages of using these technologies.

2.9.7 Discuss how life in different eras was affected by the transfer of glass and mirror manufacturing technologies from one society to another.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.10 Analyze light reflected from mirrors of different shapes, by solving problems and doing exercises involving the use of ray diagrams.

PREREQUISITES:

2.2, 2.3, 2.4, 2.6

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-1)
–	**KNOWLEDGE:**	Law of reflection, field of vision, principal focus, secondary principal focus, radius of curvature, centre of curvature, principal axis, principal rays, normal. (A-7)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Elegance of proposed solution.
D.	**MATERIALS:**	Plane mirrors, cylindrical mirrors, ray box, source of laser light, protractor, pins, ruler.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

2.10.1 Read each problem carefully, identifying the data needed to solve it.

2.10.2 Draw a diagram of the situation described in each problem.

2.10.3 Indicate on these diagrams the physical quantities called for in each problem, if necessary.

2.10.4 Relate the appropriate units of measure to the physical quantities used in each problem, if necessary.

2.10.5 Use the necessary mathematical operators correctly in solving each problem.

2.10.6 Verify the plausibility of the answer by order of magnitude.

2.10.7 Verify the plausibility of the answer by conducting an experiment, if necessary.

2.10.8 Propose the most elegant solution possible.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 2.11 Solve problems and do exercises dealing with examples of non-optical reflection.

PREREQUISITES:

2.4, 2.5, 2.6, 2.7

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-1)
–	**KNOWLEDGE:**	Law of reflection for other physical phenomena. (A-10)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' ability to draw diagrams.
D.	**MATERIALS:**	Mirrors (i.e. plane, cylindrical, spherical, parabolic), sources of sound, ripple tank, ray box, protractor, Bristol board, pins, ruler.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

CS-42

LEARNING ACTIVITIES

THE STUDENTS:

2.11.1 Read each problem carefully, identifying the data needed to solve it.

2.11.2 Draw a diagram of the situation described in each problem.

2.11.3 Indicate on these diagrams the physical quantities called for in each problem, if necessary.

2.11.4 Relate the appropriate units of measure to the physical quantities used in each problem, if necessary.

2.11.5 Use the necessary mathematical operators correctly in solving each problem.

2.11.6 Verify the plausibility of the answer by order of magnitude.

2.11.7 Verify the plausibility of the answer by conducting an experiment, if necessary.

2.11.8 Propose the most elegant solution possible.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3 **Analyze the behaviour of light refracted by different substances, by referring to their observations of light phenomena in their environment and to laboratory experiments they have conducted.**

3.1 Identify everyday examples of refracted light.

PREREQUISITES:

1

RELATED CONTENT:

–	**SKILL:**	Observing. (B-1)
–	**KNOWLEDGE:**	Refraction, historical developments, refractive power. (A-2)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, individual work, class discussion, demonstration.

B.	**DURATION:**	50 minutes in class + homework.
C.	**EVALUATION:**	Students' observations.
D.	**MATERIALS:**	Various transparent substances (solids, liquids), ray box, reference material, source of laser light.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

3.1.0 Review the concept of characteristic property of matter (Physical Sciences 416-436).

3.1.1 List examples of refracted light that occur in the natural environment and in everyday life.

3.1.2 Observe examples of refracted light during a demonstration.

3.1.3 Propose an explanation for the refraction of light.

3.1.4 Compare one another's explanations.

3.1.5 Predict the path that light will take as it passes from one transparent medium to another, using ray diagrams.

3.1.6 Compare one another's predictions and select one for further study.

3.1.7 Verify the selected prediction by conducting an experiment.

3.1.8 Relate a substance's ability to refract light to a characteristic property of matter.

3.1.9 Describe how Ptolemy's theory of refraction influenced scientists of his time.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.2 Show how light refracted by optical objects behaves, using diagrams.

PREREQUISITES:

3.1

RELATED CONTENT:

–	**SKILL:**	Observing. (B-2)
–	**KNOWLEDGE:**	Dispersion of polychromatic light, total internal reflection, refraction, historical developments. (A-10)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	50 minutes in class + homework.
C.	**EVALUATION:**	Students' interpretation.
D.	**MATERIALS:**	Set of prisms, ray box, cardboard, pins, reference material.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

CS-38, CS-42

LEARNING ACTIVITIES

THE STUDENTS:

3.2.1 Observe the behaviour of light as it passes through a prism.

3.2.2 Describe at least three optical phenomena they have observed.

3.2.3 Illustrate the phenomena they have observed, using diagrams.

3.2.4 Relate the dispersion of light to the refractive power of the substance used.

3.2.5 Relate the formation of rainbows to the dispersion of light.

3.2.6 Present Dietrich von Freiberg's (13th century) explanation for the formation of a rainbow.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.3 Propose a model of light that explains how they perceive the colour of objects in their environment.

PREREQUISITES:

3.2

RELATED CONTENT:

–	**SKILL:**	Generalizing (F-1)
–	**KNOWLEDGE:**	Spectrum of colours, polychromatic light, monochromatic light, opaque coloured objects, transparent coloured objects, translucent coloured objects, light filter, ultraviolet and infrared radiation, remote sensing technologies. (A-2)
–	**ATTITUDE:**	Self-confidence. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' models.
D.	**MATERIALS:**	Triangular prism, ray box, light sources of different colours, objects of different colours, light filters, source of laser light, spectrometer (optional).
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-50, AV-56
B-4, B-33
M-8, M-29

LEARNING ACTIVITIES

THE STUDENTS:

3.3.0 Review the features of a good model (Physical Sciences 416-436).

3.3.1 Give their own explanation for the composition of polychromatic light (white light).

3.3.2 Cause light to be dispersed by a prism.

3.3.3 Draw a diagram of the phenomenon observed in 3.3.2.

3.3.4 Indicate on their diagrams the spectral colours produced.

3.3.5 Formulate a hypothesis to explain the dispersion of one of the spectral colours they have observed.

3.3.6 Compare one another's hypotheses and select one for further study.

3.3.7 Test the selected hypothesis by conducting an experiment.

3.3.8 Propose their own theories to explain how the eye perceives the colour of opaque and transparent objects illuminated by a polychromatic light source.

3.3.9 Compare one another's proposals and select one for further study.

3.3.10 Verify the selected proposal, using light of different colours.

3.3.11 Describe the different technological uses of colour filters.

3.3.12 Discuss the different way in which the colours that make up white light are diffused in a translucent medium.

3.3.13 Discuss the characteristics and properties of types of light that are invisible to the human eye.

3.3.14 List technological applications of the properties of these types of invisible light.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.4 Determine the index of refraction for transparent substances, after conducting laboratory experiments.

PREREQUISITES:

3.2

RELATED CONTENT:

–	**SKILL:**	Constructing a model. (E-2)
–	**KNOWLEDGE:**	Snell's law (Descartes' contribution), historical developments. (A-8)
–	**ATTITUDE:**	Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' experiments and research.
D.	**MATERIALS:**	Ray box, transparent substances (lucite, glass, alcohol, water, vegetable and mineral oils, animal fats), pins, Bristol board, protractor, source of laser light.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-57, AV-69
B-17, B-19, B-24
CS-1, CS-14

LEARNING ACTIVITIES

THE STUDENTS:

3.4.1 Formulate a mathematical relationship between the angles of incidence and refraction for light that passes from air into other transparent media, after conducting experiments according to the suggested procedure.

3.4.2 Compare the results of one another's work.

3.4.3 Compare their results with the generally accepted result.

3.4.4 Learn that the mathematical relationship developed by Snell and Descartes to describe refraction was derived from al-Khwârizmî's work on sine tables in the 9th century.

3.4.5 Write a report describing the work they did in 3.4.1 to 3.4.4.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 3.5 Determine the relative index of refraction for light that passes from one transparent medium to another, by conducting an experiment.

PREREQUISITES:

3.4

RELATED CONTENT:

–	**SKILL:**	Generalizing. (F-1)
–	**KNOWLEDGE:**	Methods of measuring indices of refraction. (A-10)
–	**ATTITUDE:**	Sense of belonging. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, collective work in the laboratory, individual work, class discussion.

B.	**DURATION:**	50 minutes in class + homework.
C.	**EVALUATION:**	Students' interpretations of experimental results.
D.	**MATERIALS:**	Transparent substances, ray box, protractor, pins, Bristol board, source of laser light.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

B-9, B-12

LEARNING ACTIVITIES

THE STUDENTS:

3.5.1 Develop an experimental procedure to measure the relative index of refraction for light that passes from one medium to another, neither one of which is air.

3.5.2 Conduct a laboratory experiment.

3.5.3 Determine the relative index of refraction for light that passes from the first medium to the second medium.

3.5.4 Write their results in the table used to compile the class's results.

3.5.5 Become aware that scientific discoveries often result from teamwork.

3.5.6 Write a report describing the experiment, after discussing the results.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 3.6 Determine the apparent and real positions of an object placed in a transparent medium other than air.

PREREQUISITES:

3.4

RELATED CONTENT:

—	**SKILL:**	Measuring. (B-5)
—	**KNOWLEDGE:**	Law of refraction. (A-10)
—	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Laboratory work, individual work.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' ability to work alone.
D.	**MATERIALS:**	Ray box, transparent liquid (e.g. water, alcohol), objects, protractor, semi-circular dish, aquarium, transparent substances (e.g. lucite, glass, water), source of laser light.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

B-15, B-16

LEARNING ACTIVITIES

THE STUDENTS:

3.6.1 Observe an object placed in a transparent medium other than air.

3.6.2 Predict the path of the light rays that make the object visible, using a diagram.

3.6.3 Verify their predictions by conducting an experiment.

3.6.4 Modify their diagrams, if necessary.

3.6.5 Compare their diagrams with one that accurately represents the law of refraction for light.

3.6.6 Propose an explanation for any discrepancies between their diagrams and the one that accurately represents the law of refraction.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.7 Analyze totally internally reflected light, after conducting experiments.

PREREQUISITES:

3.4

RELATED CONTENT:

—	**SKILL:**	Developing an experimental procedure. (C-4)
—	**KNOWLEDGE:**	Critical angle, total internal reflection, fiber optics, mirage, use of optical fibers, technological aspects. (A-5)
—	**ATTITUDE:**	Creative approach (ingenuity). (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' experimental procedures.
D.	**MATERIALS:**	Ray box, source of laser light, semi-circular block of lucite or glass, semi-circular dish, aquarium, transparent liquids (e.g. water, alcohol), optical fibers, pins, Bristol board, protractor.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-1, AV-2, AV-56, AV-69
B-27, B-29, B-33, B-36
CS-14, CS-38, CS-42
M-8, M-14, M-23, M-27, M-31, M-41, M-47, M-50

LEARNING ACTIVITIES

THE STUDENTS:

3.7.1 Observe a demonstration of light that is totally internally reflected in different transparent substances.

3.7.2 Formulate a hypothesis regarding the factors that influence the value of the critical angle.

3.7.3 Compare one another's hypotheses.

3.7.4 Develop an experimental procedure to test the hypotheses that the class has deemed most plausible.

3.7.5 Conduct a laboratory experiment.

3.7.6 Determine a mathematical relationship between the critical angle and the indices of refraction for a given substance.

3.7.7 Compare one another's results.

3.7.8 Explain examples of mirages in the environment, using the concept of total internal reflection.

3.7.9 Observe the behaviour of a light beam as it travels through an optical fiber.

3.7.10 Learn how fiber-optic technology is used in medicine, telecommunications, industry and other fields.

3.7.11 Give examples of the socio-economic importance of the applications of total internal reflection.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.8 Analyze situations in which light is refracted by different substances, by solving problems and doing both numerical exercises and exercises involving graphical solutions.

PREREQUISITES:

3.2, 3.5, 3.7

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-1)
–	**KNOWLEDGE:**	Methods of calculation and graphing techniques, law of refraction. (A-7)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Methods of calculation and techniques for drawing diagrams.
D.	**MATERIALS:**	Calculator (optional), protractor, and other materials, depending on the problem.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

CS-14

LEARNING ACTIVITIES

THE STUDENTS:

3.8.1 Read each problem carefully, identifying the data needed to solve it.

3.8.2 Draw a diagram of the situation described in each problem.

3.8.3 Indicate on these diagrams the physical quantities called for in each problem, if necessary.

3.8.4 Relate the appropriate units of measure to the physical quantities used in each problem, if necessary.

3.8.5 Use the necessary mathematical operators correctly in solving each problem.

3.8.6 Verify the plausibility of the answer by means of unit analysis, if necessary.

3.8.7 Verify the plausibility of the answer by order of magnitude.

3.8.8 Verify the plausibility of the answer by conducting an experiment.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4 Analyze the characteristics of lenses, on the basis of what they have learned about the behaviour of light while doing scientific work.

4.1 Illustrate the operation of a device containing one or more lenses, using diagrams.

PREREQUISITES:

3.2

RELATED CONTENT:

–	**SKILL:**	Formulating a hypothesis (predicting). (C-2)
–	**KNOWLEDGE:**	Devices that contain lenses. (A-1)
–	**ATTITUDE:**	Fascination with science. (I-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, individual work, group work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' diagrams.
D.	**MATERIALS:**	Reference material, devices that contain lenses (e.g. camera, projector, binoculars, astronomical telescope, terrestrial telescope, microscope).
E.	**SAFETY MEASURES:**	Precautions in handling devices.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

4.1.1 List devices that contain one or more lenses.

4.1.2 Learn about other devices that operate with lenses.

4.1.3 Draw a scale diagram of a given device.

4.1.4 Identify on their diagrams the optical components of that device.

4.1.5 Predict the path that light will take when that device is used.

4.1.6 Justify their predictions.

4.1.7 Discuss one another's justifications.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.2 Differentiate among different types of lenses, after observing objects through them.

PREREQUISITES:

RELATED CONTENT:

—	**SKILL:**	Organizing data. (D-1)
—	**KNOWLEDGE:**	Converging lenses, diverging lenses (double convex, plano-convex, double concave, plano-concave, converging meniscus, diverging meniscus). (A-6)
—	**ATTITUDE:**	Critical attitude. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Individual work, group work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' classifications.
D.	**MATERIALS:**	Converging lenses (double convex, plano-convex, converging meniscus, cylindrical); diverging lenses (double concave, plano-concave, diverging meniscus, cylindrical).
E.	**SAFETY MEASURES:**	Precautions in handling lenses and glass.

SUGGESTED REFERENCES:

B-1, B-18, B-28
CS-1, CS-42

LEARNING ACTIVITIES

THE STUDENTS:

4.2.1 Observe objects in their environment through different lenses.

4.2.2 Classify, according to their physical characteristics, the lenses they have used.

4.2.3 Compare one another's classifications.

4.2.4 Distinguish between converging and diverging lenses, after comparing the path that light takes in each case.

4.2.5 Become aware of the diagram for each type of lens.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.3 Analyze the behaviour of light refracted by lenses, after conducting experiments.

PREREQUISITES:

4.2

RELATED CONTENT:

–	**SKILL:**	Measuring. (G-2)
–	**KNOWLEDGE:**	Focal length, principal rays, principal points, optical power, dioptre, historical developments. (A-10)
–	**ATTITUDE:**	Objectivity. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	50 minutes in class + homework.
C.	**EVALUATION:**	Students' measurements.
D.	**MATERIALS:**	Converging lenses made of different materials, diverging lenses, corrective lenses (glasses), optical bench, ray box, screen, cylindrical converging lenses, cylindrical diverging lenses, reference material.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-58, AV-73
B-8, B-10
CS-1, CS-14, CS-21, CS-24

LEARNING ACTIVITIES

THE STUDENTS:

4.3.1 Observe objects through a lens.

4.3.2 Predict the path that light rays will follow as they pass through a lens, using diagrams.

4.3.3 Compare one another's hypotheses.

4.3.4 Test their hypotheses by conducting an experiment.

4.3.5 Estimate the focal length of different lenses by focusing light rays on a screen.

4.3.6 Determine the focal length of different lenses, after conducting experiments.

4.3.7 Compare their measurements with their estimates.

4.3.8 Relate the focal length of each lens to its radius of curvature.

4.3.9 Relate the refraction of light by a lens to the refractive index of the lens material.

4.3.10 Relate the optical power of a lens to its focal length.

4.3.11 Determine the optical power of the lenses used in 4.3.6.

4.3.12 Describe how a glass bottle can cause a fire in the environment, using the knowledge they have acquired.

4.3.13 Show that experimentation is essential to the understanding of phenomena by referring to the work of Giambattista della Porta (14th century).

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.4 Determine the optical power of a lens system, after conducting experiments.

PREREQUISITES:

4.3

RELATED CONTENT:

–	**SKILL:**	Generalizing. (D-6)
–	**KNOWLEDGE:**	Optical power of a system of lenses: ($P_t = P_1 + P_2 + \ldots + P_n$), dioptre, chromatic aberration. (A-5)
–	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' ability to synthesize and apply knowledge.
D.	**MATERIALS:**	Converging lenses, diverging lenses, combination of lenses, object plate, screen, optical bench, devices containing a lens system, reference material.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-56
B-6
CS-14
M-33

LEARNING ACTIVITIES

THE STUDENTS:

4.4.1 Predict the optical power of a system containing lenses whose focal lengths are known.

4.4.2 Verify one of their predictions by conducting an experiment.

4.4.3 Determine a mathematical relationship between the optical power of each lens in a system and the optical power of that system.

4.4.4 Identify optical devices in their environment that contain a lens system.

4.4.5 Relate the power of an optical device to the optical power of its lens system.

4.4.6 Discuss the advantage of using a lens system.

4.4.7 Relate the task of measuring the optical power of corrective lenses to the work of optometrists, opticians and eye doctors.

4.4.8 Assess the impact of Galileo's study of optics (17th century) on the development of experimental science, after consulting reference materials.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 4.5 Test their understanding of the behaviour of refracted light, using black boxes.

PREREQUISITES:

3.3, 3.6, 4.3, 4.4

RELATED CONTENT:

—	**SKILL:**	Generalizing. (F-1)
—	**KNOWLEDGE:**	Behaviour of refracted light. (A-10)
—	**ATTITUDE:**	Creative approach. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Laboratory work, group work, individual work, simulation, class discussion, educational game.

B.	**DURATION:**	100 minutes.
C.	**EVALUATION:**	Students' solutions.
D.	**MATERIALS:**	Converging lenses, rectangular prism, triangular prism, diverging lenses, black boxes containing optical objects assembled by the students, optical bench, source of laser light, ray box, screen.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-59
B-1, B-4, B-7
CS-24
M-28

LEARNING ACTIVITIES

THE STUDENTS:

4.5.1 Observe the behaviour of light as it passes through an assembly of optical objects hidden in a black box.

4.5.2 Propose diagrams for these hidden assemblies.

4.5.3 Verify their proposals by assembling the objects represented in their diagrams.

4.5.4 Create black boxes containing an assembly of optical objects that their classmates must identify.

4.5.5 Identify hidden assemblies that their classmates have created.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.6 Analyze situations in which light is refracted by lenses of different shapes, by solving problems and doing exercises.

PREREQUISITES:

4.2, 4.3, 4.4

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-1)
–	**KNOWLEDGE:**	Methods of calculation and techniques for drawing diagrams, mathematical relationships among the characteristics of lenses, behaviour of light. (A-7)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Methods of calculation and techniques for drawing diagrams.
D.	**MATERIALS:**	Converging lenses, diverging lenses, optical bench, object plate, source of laser light, screen, calculator (optional).
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-58
CS-1, CS-24

LEARNING ACTIVITIES

THE STUDENTS:

4.6.1 Read each problem carefully, identifying the data needed to solve it.

4.6.2 Draw a diagram of the situation described in each problem.

4.6.3 Indicate on these diagrams the physical quantities called for in each problem, if necessary.

4.6.4 Relate the appropriate units of measure to the physical quantities used in each problem, if necessary.

4.6.5 Use the necessary mathematical operators correctly in solving each problem.

4.6.6 Verify the plausibility of the answer by means of unit analysis, if necessary.

4.6.7 Verify the plausibility of the answer by order of magnitude.

4.6.8 Verify the plausibility of the answer by conducting an experiment, if necessary.

4.6.9 Propose the most elegant solution possible.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5 **Analyze the characteristics of images formed by optical devices, on the basis of their experimental results and using the skills and knowledge acquired while studying the reflection and refraction of light.**

5.1 Determine the characteristics of images formed by converging lenses, after conducting experiments.

PREREQUISITES:

4.3

RELATED CONTENT:

–	**SKILL:**	Observing. (B-2)
–	**KNOWLEDGE:**	Characteristics of images formed by a converging lens, diagrams showing the location of images formed by a converging lens. (A-6)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	150 minutes in class + homework.
C.	**EVALUATION:**	Students' diagrams showing the location of images formed by a converging lens.
D.	**MATERIALS:**	Object plate, converging lenses, screen, optical bench, ruler.
E.	**SAFETY MEASURES:**	Precautions in handling technical objects.

SUGGESTED REFERENCES:

B-8, B-14, B-16
CS-12

LEARNING ACTIVITIES

THE STUDENTS:

5.1.1 Observe images of an object through a converging lens placed at various distances from the object.

5.1.2 Describe what they have observed.

5.1.3 Identify specific areas in front of the lens, on the basis of the different image characteristics they have observed.

5.1.4 Compare one another's descriptions.

5.1.5 Determine the characteristics of images of an object plate placed at various distances from a converging lens, while that image is projected on a screen.

5.1.6 Record in a data table they have created the observable characteristics of the images formed by the lens.

5.1.7 Describe the change in the characteristics of the image of an object plate as it is moved closer to a converging lens, using diagrams.

5.1.8 Write a report describing their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.2 Determine the characteristics of images formed by a concave mirror, after conducting experiments.

PREREQUISITES:

2.8

RELATED CONTENT:

—	**SKILL:**	Observing. (B-2)
—	**KNOWLEDGE:**	Characteristics of images formed by a concave mirror, diagrams showing the location of real and virtual images. (A-3)
—	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' diagrams showing the location of images formed by a concave mirror.
D.	**MATERIALS:**	Object plate, concave mirrors, screen, optical bench, protractor, ruler.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

B-7, B-8, B-9

LEARNING ACTIVITIES

THE STUDENTS:

5.2.1 Observe the images of objects placed at various locations in front of a concave mirror.

5.2.2 Describe the images they have observed.

5.2.3 Identify specific areas in front of the mirror, on the basis of the different image characteristics they have observed.

5.2.4 Compare one another's descriptions.

5.2.5 Predict the characteristics of the images of objects placed at various locations in front of a concave mirror, using diagrams and their knowledge of the laws of reflection.

5.2.6 Compare one another's predictions and select some of them for further study.

5.2.7 Develop an experimental procedure to verify the selected predictions.

5.2.8 Record in a data table they have created the observable characteristics of the images formed by the mirror.

5.2.9 Distinguish between a real image and a virtual image.

5.2.10 Show that a virtual image can be located by extending light rays that are reflected back towards the observer's eye, using diagrams.

5.2.11 Describe the change in the characteristics of the image of an object as it is moved closer to a concave mirror, using diagrams.

5.2.12 Write a report describing their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.3 Determine the characteristics of images formed by a diverging lenses, after conducting experiments.

PREREQUISITES:

5.1

RELATED CONTENT:

—	**SKILL:**	Observing. (B-2)
—	**KNOWLEDGE:**	Characteristics of images formed by a diverging lens, diagrams showing the location of images formed by a diverging lens. (A-10)
—	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' diagrams showing the location of images formed by a diverging lens.
D.	**MATERIALS:**	Object plate, diverging lenses, screen, optical bench.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-69

LEARNING ACTIVITIES

THE STUDENTS:

5.3.1 Observe images of objects placed at various locations in front of a diverging lens.

5.3.2 Describe the images they have observed.

5.3.3 Compare one another's descriptions.

5.3.4 Predict the characteristics of the images of objects placed at various locations in front of a diverging lens, using diagrams.

5.3.5 Compare one another's predictions and select some of them for further study.

5.3.6 Verify the selected predictions by conducting an experiment.

5.3.7 Correct their diagrams, if necessary.

5.3.8 Describe the change in the characteristics of the image of an object as it moves closer to a diverging lens, using a diagram.

5.3.9 Record their observations in the table created in 5.1.6.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.4 Determine the characteristics of images formed by a convex mirror, after conducting experiments.

PREREQUISITES:

2.8, 5.2

RELATED CONTENT:

–	**SKILL:**	Observing. (B-2)
–	**KNOWLEDGE:**	Characteristics of images formed by a convex mirror, diagrams showing the location of images formed by a convex mirror. (A-3)
–	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Students' diagrams showing the location of images formed by a convex mirror.
D.	**MATERIALS:**	Object plate, convex mirrors, screen, optical bench, protractor, ruler.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

B-5, B-8, B-9

LEARNING ACTIVITIES

THE STUDENTS:

5.4.1 Observe images of objects placed at various locations in front of a convex mirror.

5.4.2 Describe the images they have observed.

5.4.3 Compare one another's descriptions.

5.4.4 Predict the characteristics of the images formed by a convex mirror, using diagrams.

5.4.5 Compare one another's predictions and select some of them for further study.

5.4.6 Verify the selected predictions by conducting an experiment.

5.4.7 Draw diagrams of the images they have observed.

5.4.8 Describe the change in the characteristics of the image of an object as it is moved closer to a convex mirror, using a diagram.

5.4.9 Record their observations in the table created in 5.2.8.

5.4.10 Predict the characteristics of images formed by a mirror that produces distorted images, using a diagram.

5.4.11 Verify their predictions by conducting an experiment.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.5 Determine the characteristics of images formed by a plane mirror, after conducting experiments.

PREREQUISITES:

5.3

RELATED CONTENT:

–	**SKILL:**	Generalizing. (F-1)
–	**KNOWLEDGE:**	Location and characteristics of images formed by a plane mirror. (A-10)
–	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN:

A.	**TEACHING STRATEGY:**	
	Group work, laboratory work, individual work, class discussion.	
B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' ability to synthesize and apply knowledge.
D.	**MATERIALS:**	Ray box, plane mirrors, pins, protractor, Bristol board, reference material.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

M-21

LEARNING ACTIVITIES

THE STUDENTS:

5.5.1 Observe images of objects placed at various locations in front of a plane mirror.

5.5.2 Describe the images they have observed.

5.5.3 Compare one another's descriptions.

5.5.4 Predict the characteristics of the images of objects placed at various locations in front of a plane mirror, using diagrams.

5.5.5 Verify their predictions by conducting an experiment.

5.5.6 Correct their diagrams, if necessary.

5.5.7 Record in a data table they have created the observable characteristics of images formed by a plane mirror.

5.5.8 Relate the *House of Mirrors* found in an amusement park to the images formed by plane mirrors.

5.5.9 Give examples of how mirrors have affected the quality of life.

5.5.10 Give examples of how mirrors can influence the quality of a measurement.

5.5.11 Write a report describing their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 5.6 Determine a relationship between the number of images formed by two plane mirrors and the value of the angle between these two mirrors, on the basis of what they have observed in the laboratory.

PREREQUISITES:

5.5

RELATED CONTENT:

–	**SKILL:**	Formulating a hypothesis (predicting). (C-2)
–	**KNOWLEDGE:**	Mathematical relationship between the number of images formed by two plane mirrors and the angle between those mirrors. (A-5)
–	**ATTITUDE:**	Intellectual curiosity. (H-2)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' ray tracing of non-reversed images formed by double reflection.
D.	**MATERIALS:**	Plane mirrors, protractor, objects.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-69
B-1, B-9
M-21

LEARNING ACTIVITIES

THE STUDENTS:

5.6.1 List devices or situations that enable them to see multiple images of the same object.

5.6.2 Predict where the images of an object would be located if that object were between two plane mirrors joined at 90°.

5.6.3 Conclude that one of the images formed by these mirrors is a non-reversed image that results from double reflection.

5.6.4 Determine the location of the non-reversed image that results from double reflection, by drawing a diagram.

5.6.5 Formulate a hypothesis regarding the number of images formed by two plane mirrors if the angle between those mirrors is acute.

5.6.6 Compare one another's hypotheses and select one for further study.

5.6.7 Verify the selected hypothesis by conducting an experiment.

5.6.8 Propose a mathematical relationship between the number of images formed by two plane mirrors and the value of the angle between these mirrors.

5.6.9 Compare one another's proposals and select one for further study.

5.6.10 Verify the selected proposal by conducting an experiment.

5.6.11 Draw a diagram representing their experimental results.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.7 Determine mathematical relationships among the characteristics of images formed by a lens, on the basis of measurements made in the laboratory.

PREREQUISITES:

5.2, 5.4

RELATED CONTENT:

–	**SKILL:**	Constructing a model. (E-2)
–	**KNOWLEDGE:**	Mathematical relationships that define the magnification of lenses, location of objects, of images and of the foci of lenses, optical power, lensmaker's equation. (A-11)
–	**ATTITUDE:**	Concern for the use of correct language. (F-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' mathematical relationships.
D.	**MATERIALS:**	Converging lenses, object plate, ruler, optical bench, ray box, pins, Bristol board.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

5.7.1 Learn about the symbols used in lens diagrams to represent the following variables: focal length, the distance between the image and the lens, between the object and the lens, between the image and the focus, and between the object and the focus.

5.7.2 Develop an experimental procedure to measure the focal length of a given converging lens.

5.7.3 Conduct a laboratory experiment.

5.7.4 Determine the mathematical relationships between the characteristics of images formed by a converging lens and the characteristics of an object plate, after conducting an experiment according to the suggested procedure.

5.7.5 Discuss the applicability of the relationships discovered when they solved problems dealing with the images formed by a diverging lens.

5.7.6 Write a report describing their work.

5.7.7 Learn about the lensmaker's equation used to calculate the optical power of a lens.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 5.8 Determine the mathematical relationships among the characteristics of images formed by a curved mirror, on the basis of their knowledge of geometry.

PREREQUISITES:

5.1, 5.3

RELATED CONTENT:

–	**SKILL:**	Constructing a model. (E-2)
–	**KNOWLEDGE:**	Mathematical relationships that define the magnification of concave mirrors, location of objects, of images and of the foci of concave mirrors. (A-11)
–	**ATTITUDE:**	Concern for the use of correct language. (F-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Presentation, individual work, class discussion.

B.	**DURATION:**	100 minutes.
C.	**EVALUATION:**	Students' mathematical relationships.
D.	**MATERIALS:**	Not applicable.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

B-1, B-10, B-16, B-18, B-28

LEARNING ACTIVITIES

THE STUDENTS:

5.8.0 Review the concept of similarity between two triangles (Mathematics 416).

5.8.1 Determine the location of the real image of an object plate placed in front of a concave mirror, using a diagram of the principal rays.

5.8.2 Determine mathematical relationships that define the magnification of the mirror mentioned in 5.8.1, using similar triangles.

5.8.3 Learn about other mathematical relationships among the characteristics of concave mirrors.

5.8.4 Connect the mathematical relationships determined in 5.8.2 and 5.8.3 with those pertaining to the lenses examined in 5.7.

5.8.5 Discuss the applicability of the relationships discovered when they solved problems dealing with the images formed by convex or plane mirrors.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.9 Identify ways of correcting visual abnormalities, using their knowledge of lenses.

PREREQUISITES:

4.3, 5.1, 5.3

RELATED CONTENT:

—	**SKILL:**	Generalizing. (F-1)
—	**KNOWLEDGE:**	Ways of correcting visual abnormalities (e.g. myopia, hyperopia, presbyopia, astigmatism), eyesight of certain animals. (A-10)
—	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (I-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Presentation, group work, collective work in the laboratory, individual work, class discussion, field trip.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' knowledge of eyecare occupations and of ways of correcting visual abnormalities.
D.	**MATERIALS:**	Reference material, model of the eye, object plate, corrective lenses, ruler, compass.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-58, AV-69, AV-73
B-13, B-33
CS-38
M-20, M-47

LEARNING ACTIVITIES

THE STUDENTS:

5.9.0 Review the sense of sight and the anatomy of the eye (Biology 314).

Review the different visual abnormalities (Biology 314).

5.9.1 Predict the path that light rays will follow as they strike the retina of a person suffering from myopia, hyperopia, presbyopia or astigmatism, using diagrams.

5.9.2 Compare one another's predictions.

5.9.3 Propose ways of correcting the abnormalities mentioned in 5.9.1.

5.9.4 Compare one another's proposals and select some of them for further study.

5.9.5 Verify one of the selected proposals by conducting an experiment.

5.9.6 Record their observations in the table used to compile the class's results.

5.9.7 Describe different types of eyesight among animals, after consulting reference materials.

5.9.8 Describe how Alhazen's (Ibn al-Haytham, 11th century) work on the theory of vision influenced scientists of his time.

5.9.9 After consulting reference materials, show how Francisco Maurilico (16th century) disproved the ancient theory of vision.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 5.10 Determine a mathematical relationship for calculating the magnification of an eyepiece (magnifying glass), after conducting an experiment and determining the average minimum distance for distinct vision.

PREREQUISITES:

5.8

RELATED CONTENT:

–	**SKILL:**	Measuring. (B-3)
–	**KNOWLEDGE:**	Magnification of an eyepiece: ($M = q/l_f + 1$). (A-4)
–	**ATTITUDE:**	Fascination with science. (H-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Laboratory work, group work, individual work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' measurements.
D.	**MATERIALS:**	Magnifying glass, ruler, optical instruments containing one or more eyepieces.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

B-24, B-36

LEARNING ACTIVITIES

THE STUDENTS:

5.10.0 Review the concept of minimum distance for distinct vision in the human eye (Human Biology 314).

5.10.1 Estimate the minimum distance for distinct vision for their eyes.

5.10.2 Estimate the focal length of the eyepiece of a given optical instrument by conducting an experiment.

5.10.3 Estimate the image distance for an object viewed through a given eyepiece, by conducting an experiment.

5.10.4 Calculate the magnification of the given eyepiece, using the mathematical relationship established in 5.8.

5.10.5 Justify using the concept of minimum distance for distinct vision to calculate the magnification of an optical instrument, after consulting reference materials.

5.10.6 Explain why the left eyepiece in a pair of binoculars is equipped with adjustments.

5.10.7 Distinguish between the terms "magnification" and "magnifying power", after consulting reference materials.

5.10.8 Write a report describing their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 5.11 Explain the principle behind motion-picture making, after conducting laboratory experiments.

PREREQUISITES:

5.9

RELATED CONTENT:

—	**SKILL:**	Generalizing. (F-2)
—	**KNOWLEDGE:**	Periodic phenomena, period, frequency, persistence of vision, principle behind motion-picture making, stroboscopic effect. (A-10)
—	**ATTITUDE:**	Fascination with science. (H-6)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, individual work, demonstration, class discussion.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' explanation.
D.	**MATERIALS:**	Chronometer, wheel, pendulum, electronic stroboscope, manual stroboscope, electric rotator, wave demonstrator, fan, perforated disk, projector, films, reference material.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

CS-3, CS-20
M-34, M-40

LEARNING ACTIVITIES

THE STUDENTS:

5.11.0 Review the concept of magnetic remanence (Physical Sciences 416-436, Module 2).

Review the concept of persistence of vision (Biology 314).

5.11.1 Compare one another's explanation of the principle behind motion-picture making.

5.11.2 Compare the frequency of motion-picture frames in different eras, after consulting reference materials.

5.11.3 Formulate a hypothesis to explain the illusion of continuous motion created in a motion picture.

5.11.4 Compare one another's hypotheses.

5.11.5 Formulate a hypothesis to explain the visual effect of arrested movement that occurs in a motion picture.

5.11.6 Compare one another's hypotheses.

5.11.7 Determine the frequency of an object in periodic motion, using a stroboscope.

5.11.8 Learn that the illusion of objects in periodic motion appearing to be stationary on a movie screen is an example of a stroboscopic effect.

5.11.9 Become aware of various types of film production techniques (e.g. Cinemascope, three-dimensional film, 180° cinema, 360° cinema).

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 5.12 Illustrate how images are formed by optical instruments, using diagrams.

PREREQUISITES:

4.3, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10

RELATED CONTENT:

–	**SKILL:**	Constructing a model. (E-2)
–	**KNOWLEDGE:**	Characteristics of images formed by optical devices, path taken by light rays that travel through optical devices. (A-10)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, working collectively in the laboratory, individual work.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' model.
D.	**MATERIALS:**	Binoculars, terrestrial telescope, astronomical telescope, microscope, projector, telescope, stereoscope, periscope..., converging lenses, plane mirrors, concave mirrors, optical bench, object plate, screen, ruler.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-58, AV-69, AV-73
B-8, B-12
CS-1, CS-14, CS-25
M-49

LEARNING ACTIVITIES

THE STUDENTS:

5.12.1 Describe the components of different optical devices, using scale diagrams. (e.g. binoculars, terrestrial telescope, astronomical telescope, microscope, projector, telescope, periscope, stereoscope).

5.12.2 Predict the path that light must take so that objects can be observed through different optical devices.

5.12.3 Compare one another's predictions.

5.12.4 Simulate the formation of images produced by a given optical device, using an optical bench.

5.12.5 Correct their diagrams, if necessary.

5.12.6 Present the results of their investigations.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.13 Analyze the characteristics of images formed by optical objects (mirrors, lenses), by solving problems and doing graphical and numerical exercises.

PREREQUISITES:

2.4, 4.4, 5.1, 5.2, 5.3, 5.4, 5.5, 5.7, 5.9

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-3)
–	**KNOWLEDGE:**	Methods of calculation and graphing techniques, mathematical relationships among the characteristics of images formed by optical objects. (A-7)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	150 minutes in class + homework.
C.	**EVALUATION:**	Methods of calculation and techniques for drawing diagrams.
D.	**MATERIALS:**	Protractor, plane, concave and convex mirrors, converging and diverging lenses, model of the eye, camera, projector, optical bench, source of laser light, object plate, screen.
E.	**SAFETY MEASURES:**	Safe use of laser, precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

5.13.1 Read each problem carefully, identifying the data needed to solve it.

5.13.2 Draw a diagram of the situation described in each problem.

5.13.3 Indicate on these diagrams the physical quantities called for in each problem, if necessary.

5.13.4 Relate the appropriate units of measure to the physical quantities used in each problem, if necessary.

5.13.5 Use the necessary mathematical operators correctly in solving each problem.

5.13.6 Verify the plausibility of the answer by means of unit analysis, if necessary.

5.13.7 Verify the plausibility of the answer by order of magnitude.

5.13.8 Verify the plausibility of the answer by conducting an experiment.

5.13.9 Explain the discrepancies between the measurements and the calculated results.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

6 **Make a study showing how the development of knowledge in the field of optics has affected other branches of science, technology, society and the environment.**

6.1 Describe how knowledge in the field of optics has developed throughout history, after consulting reference materials.

PREREQUISITES:

RELATED CONTENT:

–	**SKILL:**	Communicating. (F-4)
–	**KNOWLEDGE:**	Development of scientific knowledge in the field of optics. (A-1)
–	**ATTITUDE:**	"Constructivist" view of science. (I-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Individual work, group work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' reasoning.
D.	**MATERIALS:**	Reference material.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-69,
B-17, B-19
M-42

LEARNING ACTIVITIES

THE STUDENTS:

6.1.0 Review the history of science (General History 214, I.T.T. 314, History of Québec and Canada 414).

6.1.1 Describe how the work of different scientists influenced the development of knowledge in the field of optics at different points in history (e.g. Euclid, Hero, Archimedes, Ptolemy, Kepler, Galileo, Newton, Roemer, Bradley, Fizeau, Foucault, Michelson).

6.1.2 Show how knowledge of the behaviour of light was "constructed" throughout history, by referring to the work of different scientists.

6.1.3 Give examples of how the development of knowledge in the field of optics has influenced the arts (e.g. visual and plastic arts) and other branches of science (e.g. biology, astronomy).

6.1.4 Write a report on their readings.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

6.2 Analyze the impact of the development of optical technology on the quality of human life, after consulting reference materials.

PREREQUISITES:

6.1

RELATED CONTENT:

—	**SKILL:**	Generalizing. (F-1)
—	**KNOWLEDGE:**	Impact of the development of optical technology on the quality of human life. (A-1)
—	**ATTITUDE:**	Sense of responsibility. (H-7)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, individual work, group work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' ability to communicate.
D.	**MATERIALS:**	Reference material.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-58, AV-73
B-27
M-18, B-29, M-49

LEARNING ACTIVITIES

THE STUDENTS:

6.2.1 Identify optical technologies that have affected the quality of human life at different points in history.

6.2.2 Describe how optical technologies have affected the quality of human life.

6.2.3 Discuss the advantages and disadvantages of these technologies.

6.2.4 Write a report describing their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

6.3 Describe Québec's contribution to research and development in the field of optics, after consulting reference materials.

PREREQUISITES:

RELATED CONTENT:

–	**SKILL:**	Recognizing a problem. (C-1)
–	**KNOWLEDGE:**	Organizations involved in optics research in Québec, optical products made in Québec, social and economic impact of these activities. (A-1)
–	**ATTITUDE:**	Sense of belonging. (H-7)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Individual work, group work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' paper.
D.	**MATERIALS:**	Reference material.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-1, AV-2

LEARNING ACTIVITIES

THE STUDENTS:

6.3.1 Identify the latest research in optics, after consulting reference material.

6.3.2 Among the research projects mentioned in 6.3.1, identify those being carried out in Québec.

6.3.3 Name Québec-based firms and institutions that cooperate in the development of optics in Québec.

6.3.4 Describe at least one project or piece of research dealing with optics that has been carried out by a Québec-based firm or institution.

6.3.5 Write a short paper showing how research in optics is important for Québec society.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 6.4 Identify occupations associated with optics, after consulting reference materials.

PREREQUISITES:

5.10

RELATED CONTENT:

—	**SKILL:**	Generalizing. (F-2)
—	**KNOWLEDGE:**	Occupations associated with optics. (A-6)
—	**ATTITUDE:**	Fascination with science. (H-6)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Individual work, group work, field trip, interview.

B.	**DURATION:**	50 minutes in class + homework.
C.	**EVALUATION:**	Students' descriptions.
D.	**MATERIALS:**	Reference material.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

M-49

LEARNING ACTIVITIES

THE STUDENTS:

6.4.0 Consult career information documents (Career Choice Education 111, 211, 311, 451, 551).

6.4.1 List occupations associated with optics.

6.4.2 Distinguish between medical and non-medical occupations associated with optics.

6.4.3 Describe at least one of the occupations identified in 6.4.1, after consulting reference materials or conducting interviews.

6.4.4 Write a report describing their research.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 6.5 Discover the environmental impact of different optical technologies, after consulting reference materials.

PREREQUISITES:

6.2

RELATED CONTENT:

–	**SKILL:**	Generalizing. (F-3)
–	**KNOWLEDGE:**	Environmental impact of the use of different optical technologies. (A-1)
–	**ATTITUDE:**	Sense of responsibility. (H-8)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Individual work, group work, class discussion.

B.	**DURATION:**	75 minutes in class + homework.
C.	**EVALUATION:**	Students' ability to communicate.
D.	**MATERIALS:**	Reference material, promotional materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

6.5.1 Find examples of the use of optical technologies, by consulting promotional materials.

6.5.2 List the advantages and disadvantages of using these technologies.

6.5.3 Assess the environmental impact of the use of these technologies.

6.5.4 Write a report describing their work.

TEACHER'S NOTES:

MODULE 2

OPTICAL DEVICES

MODULE OBJECTIVE: To help students broaden their scientific knowledge by having them construct an optical device that will enable them to apply what they have learned and to explore different technologies.

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1 **Present the results of a quantitative study that involves designing an optical measuring device in order to examine a mechanical phenomenon of their choice, using correct language.**

1.1 Design an optical device to measure one or more variables associated with a mechanical phenomenon of their choice.

PREREQUISITES:

Module 1; Module 3, Terminal Objective 3

RELATED CONTENT:

–	**SKILL:**	Recognizing a problem. (C-1)
–	**KNOWLEDGE:**	Optical measuring devices, variables associated with mechanical phenomena. (A-10)
–	**ATTITUDE:**	Intellectual curiosity. (H-5)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, demonstrations, meeting between the teacher and each student.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' ability to define a problem.
D.	**MATERIALS:**	Appropriate reference material, appropriate laboratory materials and equipment.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-1, AV-2, AV-56, AV-57, AV-58, AV-59, AV-60, AV-67, AV-69, AV-70, AV-71, AV-73
B-6, B-8, B-9, B-13, B-15, B-17, B-19, B-29, B-30, B-31, B-32
CS-7
M-1, M-3, M-4, M-5, M-13, M-16, M-23, M-24, M-25, M-28, M-31, M-32, M-33, M-34, M-36, M-37, M-38, M-39, M-46, M-51

LEARNING ACTIVITIES

THE STUDENTS:

1.1.1 Identify mechanical phenomena that they find interesting, on the basis of what they have observed in the environment or in a laboratory.

1.1.2 Select the variable(s) they intend to measure in studying a particular mechanical phenomenon.

1.1.3 Using conventional symbols, draw a diagram of an optical device that can measure the variable(s) they have selected.

1.1.4 Identify the different components they will use to construct their optical devices.

1.1.5 Submit their projects for approval.

TEACHER'S NOTES:

Topics That Could Be Explored in Order to Achieve the Objective of This Module

Variables

- Time
- Length
- Distance (e.g. path/trajectory)
- Displacement (e.g. range, maximum height)
- Speed/velocity
- Acceleration (e.g. gravitational)
- Force (e.g. gravitational, frictional)
- Coefficient (e.g. friction, elasticity, restitution, dilation)
- Physical constants (e.g. spring constant, gravitation, coulomb, speed of light)
- Surface pressure, pressure in fluids
- Energy (e.g. kinetic, potential)
- Impulse
- Linear momentum

Phenomena and Techniques

- Photography
- Strobe photography
- Chronophotography
- Cinematography
- Reflection of objects and of light waves
- Refraction of objects and waves
- Dispersion
- Diffraction
- Modulation of light waves (laser)
- Interference of light and sound waves

Types of Movement

- Acrobats
- Athletes
- Ballerinas, dancers
- Running mammals
- Birds in flight
- Fish in an aquarium
- Reptiles on the ground
- Children's toys
- Amusement park rides
- Projectiles in sport (e.g. movement of a hockey puck, a baseball)

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.2 Measure the variable(s) associated with the mechanical phenomenon they have decided to study, using the optical measuring devices they have designed.

PREREQUISITES:

1.1

RELATED CONTENT:

–	**SKILL:**	Measuring. (G-2)
–	**KNOWLEDGE:**	Conducting an experiment according to a specific procedure. (A-7)
–	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-2)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, meeting between the teacher and each student.

B.	**DURATION:**	250 minutes in class + homework.
C.	**EVALUATION:**	Students' measurements.
D.	**MATERIALS:**	Reference material, appropriate laboratory materials and equipment.
E.	**SAFETY MEASURES:**	Precautions in handling all laboratory materials and equipment, including any source of laser light or high voltage.

SUGGESTED REFERENCES:

B-13, B-17, B-18, B-19, B-22, B-32
M-15, M-16, M-17

LEARNING ACTIVITIES

THE STUDENTS:

1.2.1 Develop an experimental procedure to measure the variable(s) they have selected.

1.2.2 Include in their procedures a list of materials, equipment and reference materials that they plan to use for their project.

1.2.3 Determine the way in which the results of the research project might be presented, given the available resources.

1.2.4 Prepare a schedule of the work to be done, on the basis of the time allotted for this project.

1.2.5 Find the reference material, equipment and materials needed for their research work.

1.2.6 Submit their research plans for approval.

1.2.7 Construct their optical measuring devices.

1.2.8 Measure the variable(s) they have selected.

1.2.9 Compile their observations and results in a data table they have designed.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.3 Critically analyze the results obtained in 1.2, in order to improve the optical measuring devices they have designed.

PREREQUISITES:

1.2

RELATED CONTENT:

–	**SKILL:**	Generalization. (D-6)
–	**KNOWLEDGE:**	Features of a good optical measuring device, approximate nature of a measurement. (A-1)
–	**ATTITUDE:**	Objectivity. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, meeting between the teacher and each student.

B.	**DURATION:**	100 minutes in class + homework.
C.	**EVALUATION:**	Students' critical analysis.
D.	**MATERIALS:**	Depending on the changes required for each optical measuring device.
E.	**SAFETY MEASURES:**	Depending on the changes required for each optical measuring device.

SUGGESTED REFERENCES:

CS-37
M-15, M-16, M-17

LEARNING ACTIVITIES

THE STUDENTS:

1.3.1 Analyze the data compiled while doing research.

1.3.2 Ensure that their optical measuring devices are not responsible for an incorrect interpretation of the phenomenon they are studying.

1.3.3 Suggest changes that would improve their optical measuring devices, if necessary.

1.3.4 Verify the effectiveness of the changes they have made.

1.3.5 Analyze the new data they have compiled.

1.3.6 Formulate a conclusion.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.4 Present the results of their quantitative study of the mechanical phenomenon they have selected.

PREREQUISITES:

1.3

RELATED CONTENT:

–	**SKILL:**	Communicating. (F-4)
–	**KNOWLEDGE:**	Methods and techniques for presenting a research report. (A-4)
–	**ATTITUDE:**	Concern for the use of correct language. (F-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Meeting between the teacher and each student, students' presentations, displaying exhibits.

B.	**DURATION:**	150 minutes in class + work during free time + time devoted to extracurricular activity.
C.	**EVALUATION:**	Students' presentations.
D.	**MATERIALS:**	Depending on the nature of the presentation.
E.	**SAFETY MEASURES:**	Depending on the equipment and materials needed for the presentation.

SUGGESTED REFERENCES:

B-17, B-19, B-32, B-33
CS-37
M-15, M-16, M-17, M-46

LEARNING ACTIVITIES

THE STUDENTS:

1.4.0 Review the methods and techniques for presenting a research report (Physical Sciences 416-436).

1.4.1 Write a research report, using correct language.

1.4.2 Ensure that any materials or equipment needed for their presentation are available.

1.4.3 Present the results of their research project, using the methods and techniques discussed in 1.4.0.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.5 Present the results of their study of the mechanical phenomenon they have selected, by taking part in a science fair.

PREREQUISITES:

1.3

RELATED CONTENT:

–	**SKILL:**	Communicating. (F-4)
–	**KNOWLEDGE:**	Methods and techniques for organizing an exhibit at a science fair, techniques for defending arguments in public. (A-7)
–	**ATTITUDE:**	Intellectual curiosity. (H-5)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Individual work, group work, building exhibit in a workshop, giving a presentation in public.

B.	**DURATION:**	At least 400 minutes devoted to an extracurricular activity.
C.	**EVALUATION:**	Students' presentations (evaluated according to the criteria of the science fair).
D.	**MATERIALS:**	Depending on the project and the type of exhibit involved.
E.	**SAFETY MEASURES:**	Depending on the project and the type of exhibit involved.

SUGGESTED REFERENCES:

AV-76
M-46, M-48

LEARNING ACTIVITIES

THE STUDENTS:

1.5.0 Review the methods and techniques for presenting a research report (Physical Sciences 416-436).

1.5.1 Create an exhibit according to the criteria of the science fair.

1.5.2 Present the results of their projects to the people visiting the science fair (other students and adults).

1.5.3 Defend their arguments when discussing their project with people who have questions about their work.

TEACHER'S NOTES:

MODULE 3

MECHANICS

MODULE OBJECTIVE: To investigate the motion of objects in the environment, to discover the causes of motion, and to understand the mechanical phenomena associated with it, using the scientific method.

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1 Describe the motion of objects or organisms that they have explored with their senses.

1.1 Identify various types of motion observed in objects or organisms in their environment and in the laboratory.

PREREQUISITES:

RELATED CONTENT:

–	**SKILL:**	Observing. (B-2)
–	**KNOWLEDGE:**	Distinction between rectilinear and other types of motion, trajectory, speed. (A-1)
–	**ATTITUDE:**	Intellectual curiosity. (A-6)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, presentation, individual work, group work, laboratory work, class discussion, visit and outing.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Quality of observation.
D.	**MATERIALS:**	Bicycle wheel, pendulum, slide projector, video cassette recorder, Millikan apparatus, apparatus for observing Brownian movement, air table, spark timer, projectile launcher, remote control toy car, toy roller coaster, electric train, toy race track, 1 L graduated cylinder, marbles, aquarium.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-7, AV-30, AV-31, AV-32, AV-36, AV-55, AV-74, AV-75
B-2, B-3, B-11
CS-9, CS-12, CS-13, CS-17
M-9, M-10, M-11, M-12, M-19

LEARNING ACTIVITIES

THE STUDENTS:

1.1.1 List various motions of objects or organisms in their environment.

1.1.2 Observe the motion of certain objects or organisms, using appropriate methods.

1.1.3 Classify the motions observed as rectilinear, curvilinear, or random.

1.1.4 Compare their classifications with those of their classmates.

1.1.5 Predict the behaviour of objects that move in a fluid other than air.

1.1.6 Compare their predictions with those of their classmates, and select one for further study.

1.1.7 Verify experimentally the prediction selected.

1.1.8 Compare the motion of the objects observed to the motion of other objects.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.2 Illustrate, by means of diagrams, the trajectories of moving objects observed in their immediate environment and in the laboratory.

PREREQUISITES:

1.1

RELATED CONTENT:

–	**SKILL:**	Organizing data. (G-2)
–	**KNOWLEDGE:**	Trajectory, distance travelled. (A-2)
–	**ATTITUDE:**	Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, presentation, group work, laboratory work, class discussion, visit and outing.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Quality of diagrams.
D.	**MATERIALS:**	Air table, air track, bicycle wheel, pendulum, universal support, inclined plane, film loops, software program.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-7, AV-30, AV-31, AV-32, AV-37, AV-51
B-11, B-20
CS-17, CS-23
M-12, M-48

LEARNING ACTIVITIES

THE STUDENTS:

1.2.1 Observe moving objects.

1.2.2 Represent, by means of a diagram, the trajectories of objects observed.

1.2.3 Distinguish rectilinear motion from other types of motion in the diagrams.

1.2.4 Compare their diagrams with those of their classmates.

1.2.5 Define the difference between trajectory and distance travelled.

1.2.6 Compare their definitions with those of their classmates.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.3 Describe a motion not directly observable to the naked eye, after doing a laboratory experiment.

PREREQUISITES:

1.2

RELATED CONTENT:

—	**SKILL:**	Observing. (B-2)
—	**KNOWLEDGE:**	Perception of movement through senses other than sight, the Doppler effect. (A-1)
—	**ATTITUDE:**	Intellectual curiosity. (H-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Team work, presentation, individual work.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Quality of descriptions.
D.	**MATERIALS:**	Perfumes, remote control toy car, air gun.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-68
B-11
CS-4, CS-5, CS-33

LEARNING ACTIVITIES

THE STUDENTS:

1.3.1 Estimate, by means of a sense other than sight, the motion of objects or substances.

1.3.2 Identify the sense used to estimate movements "observed" in this way.

1.3.3 Describe the trajectories of moving objects or substances, by means of diagrams.

1.3.4 Learn how to use the Doppler effect to determine the direction taken by moving objects.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 1.4 Represent a motion not directly observable by the senses, after doing an experiment in the laboratory or in the environment.

PREREQUISITES:

1.3

RELATED CONTENT:

–	**SKILL:**	Observing. (B-1)
–	**KNOWLEDGE:**	Methods of measuring slow and fast motion. (A-7)
–	**ATTITUDE:**	Objectivity. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, outing, individual work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Quality of descriptions.
D.	**MATERIALS:**	Microscope, astronomical telescope, camera, video camera, sextant, theodolite.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-30, AV-76
B-13
CS-11

LEARNING ACTIVITIES

THE STUDENTS:

1.4.1 List the instruments that permit observation of the motion of objects not directly observable by the senses.

1.4.2 Learn about other instruments for observing the motion of objects not directly observable by the senses.

1.4.3 Observe the motion of an object not directly observable by the senses, using instruments that they have constructed themselves or that they have been given.

1.4.4 Describe, by means of a diagram, the motion of the object observed.

1.4.5 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.5 Represent the trajectory of a moving object observed from different vantage points, after doing an experiment in the laboratory or in the environment.

PREREQUISITES:

1.2

RELATED CONTENT:

—	**SKILL:**	Observing. (B-2)
—	**KNOWLEDGE:**	Relative motion, relative positions. (A-1)
—	**ATTITUDE:**	Intellectual curiosity. (H-5)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, outing, individual work, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Quality of diagram.
D.	**MATERIALS:**	Map (to scale) of the constellations of the zodiac, sighting device (optional), small spheres of polystyrene, carts, camera, stroboscope, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-4, AV-5, AV-33, AV-34
B-6, B-12
M-9, M-42

LEARNING ACTIVITIES

THE STUDENTS:

1.5.1 Predict the trajectories of a moving object observed from different vantage points, using diagrams.

1.5.2 Compare their predictions with those of their classmates.

1.5.3 Observe the movement of the object from different vantage points.

1.5.4 Represent, by means of diagrams, the trajectory of the object observed from these points.

1.5.5 Compare their diagrams with those of their classmates.

1.5.6 Discuss situations from their personal experience where perception of movement depends on the point of observation.

1.5.7 Describe the roles of William IV and Frederick II in the work of Tycho Brahe (16th Century).

1.5.8 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

1.6 Illustrate, by means of vectors, the motion of objects they have observed.

PREREQUISITES:

1.5

RELATED CONTENT:

–	**SKILL:**	Recognizing a problem. (C-1)
–	**KNOWLEDGE:**	Vector drawings, vector addition, position, displacement. (A-4)
–	**ATTITUDE:**	Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	75 minutes.
C.	**EVALUATION:**	Technique of adding vectors.
D.	**MATERIALS:**	Air table, spark timer or inkjet timer, remote control toys, toy racetrack, protractor, ruler, string, nails, board, graph paper.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-3, AV-34, AV-68
B-7, B-12
CS-9
M-24

LEARNING ACTIVITIES

THE STUDENTS:

1.6.1 Observe, from a given point, the trajectory of an object moving in one plane.

1.6.2 Draw diagrams of the trajectory of the object observed.

1.6.3 Indicate on their diagrams the point from which they observed the motion.

1.6.4 Indicate the positions occupied by the object during its movement.

1.6.5 Associate the changes in position of the object with displacements.

1.6.6 Differentiate on their diagrams the displacement of the object from the distance it travels.

1.6.7 Represent the displacements of an object by means of directed line segments (vectors).

1.6.8 Discover that the total displacement of a moving object is the sum of the vectors that represent its successive displacements.

1.6.9 Discuss the usefulness of the technique of adding vectors in analyzing the motion of objects.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2 Analyze the effects of forces that they have felt or which act on objects in their environment.

2.1 Describe what they feel when a system of forces acts on them.

PREREQUISITES:

1

RELATED CONTENT:

–	**SKILL:**	Recognizing a problem. (C-1)
–	**KNOWLEDGE:**	Existence of force systems acting on the students when they are at rest or in motion. Representation of a force by means of a vector, unit of force. (A-1)
–	**ATTITUDE:**	Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, laboratory work, group work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Quality of descriptions.
D.	**MATERIALS:**	Cart, springs, elastics, cable, heavy object, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-3, AV-34
B-7, B-12

LEARNING ACTIVITIES

THE STUDENTS:

2.1.1 List experiences from daily life in which they have felt the effects of forces.

2.1.2 Describe their notions of what forces are.

2.1.3 Compare their notions with those of their classmates.

2.1.4 Feel the effect of force systems that act on them.

2.1.5 Propose scales with units for measuring forces.

2.1.6 Compare their scales with the one used in science.

2.1.7 Propose methods of representing the forces whose effects they have felt.

2.1.8 Compare their propositions with those of their classmates.

2.1.9 Represent a system of forces whose effects they have felt.

2.1.10 Discuss the position taken by Gilles Personne de Roberval (17th Century) concerning Descartes' formula, *causa sine ratio*. "*Causa sine ratio* is merely an exercise in metaphysics, unworthy of consideration by the true man of science."

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.2 Recognize the effects of forces which act on objects in their environment.

PREREQUISITES:

2.1

RELATED CONTENT:

—	**SKILL:**	Recognizing a problem. (C-1)
—	**KNOWLEDGE:**	Effect of forces, movement, rest, deformation, inertia. (A-2)
—	**ATTITUDE:**	Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, individual work, laboratory work, outing, group work, class discussion.

B.	**DURATION:**	50 minutes.
C.	**EVALUATION:**	Quality of descriptions.
D.	**MATERIALS:**	Cart, inclined plane, marbles, remote control toys, toy roller coaster, toy racetrack, swing, pendulum, bicycle wheel, gyroscope, balloon, ball, modeling clay, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-32, AV-40
B-3, B-16
CS-26

LEARNING ACTIVITIES

THE STUDENTS:

2.2.1 Apply forces, whose effect they have felt before, to objects in their environment.

2.2.2 Describe the effects of these forces on the objects.

2.2.3 Compare their descriptions with those of their classmates.

2.2.4 Divide the effects observed into two categories: changes of motion or rest state, and deformation.

2.2.5 Compare their classifications with those of their classmates.

2.2.6 Comment on Avicenna's (11th Century) assertion about inertia: "...the violent motion of a body separated from its motor would be impossible in a void because it would persist indefinitely...".

2.2.7 Describe the evolution of the concept of inertia, referring to the opinions of Aristotle, Philopon, Galileo, Beeckman, Descartes and Newton.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.3 Find the equilibrant force of a system of forces whose effects they have felt or observed, after doing an experiment.

PREREQUISITES:

2.2

RELATED CONTENT:

–	**SKILL:**	Measuring. (B-3)
–	**KNOWLEDGE:**	Technique for force vectors; resultant force, equilibrant force. (A-2)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, class discussion, group work, laboratory work, individual work.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Techniques of adding vectors.
D.	**MATERIALS:**	Air table, spring balances (dynamometers), force table, electromagnet, compass, tangent galvanometer, cart, inclined plane, spring, pulleys, cord, sets of graduated weights, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-3
B-7, B-12

LEARNING ACTIVITIES

THE STUDENTS:

2.3.1 Determine the intensity and direction of forces they have felt or of forces exerted on an object.

2.3.2 Specify the forces determined in 2.3.1, using vector drawings.

2.3.3 Determine the magnitude and direction of the equilibrant force in the force system acting on the object, using the technique for adding vectors.

2.3.4 Compare the results they obtain with those of their classmates.

2.3.5 Verify their results by doing an experiment in accordance with a suggested procedure.

2.3.6 Compare the equilibrant force and the resultant force in the force system.

2.3.7 Compare their technique of representing forces with those used by Gilles Personne de Roberval (17^{th} Century) in his *Treatise on Mechanics*.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.4 Establish a relationship between the deformation of an elastic substance and the force acting on it.

PREREQUISITES:

2.2

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-4)
–	**KNOWLEDGE:**	Hooke's law, the concept of action-reaction. (A-8)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, laboratory work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Graphic analysis.
D.	**MATERIALS:**	Elastic springs, metal wires, sets of graduated weights, Hooke's law apparatus, ruler, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-68
B-33, B-36
M-7, M-19

LEARNING ACTIVITIES

THE STUDENTS:

2.4.0 Review the concept of the properties of matter. (Physical Sciences 416-436)

2.4.1 Feel the effect of a spring that they have stretched or compressed.

2.4.2 Estimate the extension of a spring in relation to the force applied to it.

2.4.3 Compare their estimations with those of their classmates, and select one for further study.

2.4.4. Verify, by means of an experiment, the estimation selected.

2.4.5 Represent the results of their experiments in graphic form.

2.4.6 Relate the extension of a spring to the spring constant, i.e. the slope of the graph of force versus extension of the spring (Hooke's law).

2.4.7 Suggest an explanation for the value of the x-intercept on their graphs.

2.4.8 Compare their suggestions with those of their classmates.

2.4.9 After further experiments, compare the extension of the spring to the elastic deformation of other objects.

2.4.10 Define the elasticity of a solid (e.g. spring, elastic).

2.4.11 By means of reference materials, learn about Robert Hooke's work on the deformation of elastic solids (17^{th} Century).

2.4.12 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 2.5 Establish, by means of experiments, a mathematical relationship linking the factors that determine the pressure exerted on a surface.

PREREQUISITES:

2.1

RELATED CONTENT:

- **SKILL:** Observing. (G-2)
- **KNOWLEDGE:** Pressure, force, area of pressure, type of surface. (A-1)
- **ATTITUDE:** Objectivity. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B. DURATION: 75 minutes.

C. EVALUATION: Quality of laboratory work.

D. MATERIALS: Dish, geometric solids (wood, metal), sand, ruler, resource materials.

E. SAFETY MEASURES: Not applicable.

SUGGESTED REFERENCES:

AV-17, AV-46, AV-76
B-3, B-4, B-10, B-37
M-35

LEARNING ACTIVITIES

THE STUDENTS:

2.5.0 Review the concept of pressure. (Physical Sciences 214)

2.5.1 Feel the pressure exerted by different geometric solids of the same weight but of different shapes, by handling them.

2.5.2 Describe their understanding of pressure.

2.5.3 Compare their descriptions with those of their classmates.

2.5.4 List the factors which may influence the deformation of a surface to which pressure is applied.

2.5.5 Predict the effect of these factors on a surface to which pressure is applied.

2.5.6 Verify their predictions experimentally.

2.5.7 Suggest a mathematical relationship among the various factors.

2.5.8 Verify the plausibility of the suggested relationship, using unit analysis.

2.5.9 Compare their suggestions with those of their classmates.

2.5.10 Compare the relationship they decide on with the generally accepted one.

2.5.11 Look for technological applications of the concept of pressure that are to be found in their environment.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 2.6 Analyze the forces at work when an object is submerged in a liquid.

PREREQUISITES:

2.3

RELATED CONTENT:

–	**SKILL:**	Observing. (B-2)
–	**KNOWLEDGE:**	Archimedes' principle, pressure in a liquid. (A-8)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	150 minutes + homework.
C.	**EVALUATION:**	Quality of experimental verifications.
D.	**MATERIALS:**	Objects with greater and lesser density than water, overflow beaker, scales, manometer, water, alcohol, helium balloon, beaker, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

2.6.0 Review the concept of density. (Physical Sciences 214)

2.6.1 Describe what they feel when they are submerged in water (e.g. swimming pool, bathtub).

2.6.2 Compare their descriptions with those of their classmates.

2.6.3 Formulate a hypothesis to explain why an object can float in water.

2.6.4 Compare the weight of water displaced with the weight of a floating object.

2.6.5 Compare the weight of water displaced with the weight of an object completely submerged.

2.6.6 Propose an explanation for the buoyant force exerted on an object plunged into a liquid.

2.6.7 Compare their explanations with those of their classmates, and select one for further study.

2.6.8 Verify, by means of an experiment, the explanation selected.

2.6.9 Compare their results with the ones generally accepted.

2.6.10 Describe the experimental method that Archimedes (3rd Century B.C.) used to solve the problem of the gold crown of Hieron, as recounted by the Roman architect Vitruvius (1st Century B.C.).

2.6.11 Use some modern technological applications to demonstrate that Simon Stevin (16th and 17th Centuries) is rightly considered to have laid the foundations of hydrostatics.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 2.7 Recognize a reaction force when they exert an action force on an object.

PREREQUISITES:

2.3

RELATED CONTENT:

–	**SKILL:**	Recognizing a problem. (C-1)
–	**KNOWLEDGE:**	Newton's law of action/reaction, technological applications, historical evolution of the concept of action/reaction. (A-3)
–	**ATTITUDE:**	Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, brainstorming, individual work, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Ability to recognize reaction forces.
D.	**MATERIALS:**	Common objects in the environment, carts, resource materials, balloons, cords.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

2.7.1 Describe what they feel when they exert force on an object.

2.7.2 Compare their descriptions with those of their classmates.

2.7.3 Identify the causes of what they feel.

2.7.4 Connect what they feel with the reaction force of the object.

2.7.5 Estimate the quantity of the object's reaction force.

2.7.6 Justify their estimation.

2.7.7 Illustrate their concept of action/reaction with examples from daily life.

2.7.8 Compare their concept of reaction with that of Sir Isaac Newton (17^{th} Century).

2.7.9 Describe the evolution of the concept of action/reaction by referring to the work of Leonardo da Vinci (16^{th} Century), Simon Stevin (17^{th} Century) and Sir Isaac Newton.

2.7.10 Find applications of the concept of action/reaction in space technology (e.g. rocket launching, weightlessness).

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

2.8 Analyze the effects of force by solving problems, doing numerical exercises and drawing graphs.

PREREQUISITES:

2.2, 2.3

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-1)
–	**KNOWLEDGE:**	Graphic representations of force systems, vector addition. (A-7)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Calculation techniques.
D.	**MATERIALS:**	Force table, spring balances (dynamometers), calculator (optional).
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

2.8.1 Read each problem carefully, identifying the data needed to solve it.

2.8.2 Relate the appropriate units of measure to the physical quantities used in each problem.

2.8.3 Propose the most elegant solution possible.

2.8.4 Use mathematical operators correctly in solving problems.

2.8.5 Verify the plausibility of the answer using unit analysis.

2.8.6 Verify the plausibility of the answer by order of magnitude.

2.8.7 Develop a description of the effect of forces acting on objects, on the basis of the exercises they have done.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3 **Describe the movement of objects using the physical magnitudes they analyzed during experiments.**

3.1 Analyze, by means of an experiment, the positions of an object in vertical motion.

PREREQUISITES:

1.6

RELATED CONTENT:

–	**SKILL:**	Measuring. (B-3)
–	**KNOWLEDGE:**	Graph of p = f (t), average velocity, instantaneous velocity, unit of velocity, meaning of slope of p = f (t). (A-5)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	125 minutes + homework.
C.	**EVALUATION:**	Interpretation of data.
D.	**MATERIALS:**	Objects of different mass and force, spark timer or inkjet timer, recording tape, ruler, camera, stroboscope, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

3.1.0 Review the concept of rate of change (slope). (Physical Sciences 416-436, Module 2, 3.5)

3.1.1 Observe the rectilinear motion of objects falling near the ground.

3.1.2 Formulate a hypothesis about the type of motion of these objects.

3.1.3 Compare this hypothesis with those of their classmates.

3.1.4 After doing an experiment according to a suggested procedure, determine the positions of an object at different points in its motion. (For several objects, they may plot curves on one or more graphs.)

3.1.5 By means of a graph, represent the position of the object as a function of time ($p = f(t)$).

3.1.6 Compare these results with those of their classmates.

3.1.7 Describe the motion of the object, using the graph.

3.1.8 Determine the instantaneous speed of the object by calculating the slope (rate of change of position / rate of change of time) at various times for the graph of position as a function of time.

3.1.9 Verify the plausibility of these calculations by means of unit analysis.

3.1.10 During a discussion, differentiate instantaneous velocity from average velocity.

3.1.11 Write up reports of their experiments.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.2 Analyze the velocities of an object in vertical motion, from results of an experiment.

PREREQUISITES:

3.1

RELATED CONTENT:

–	**SKILL:**	Organizing Data. (D-1)
–	**KNOWLEDGE:**	Measuring velocities, area under a curve. (A-2)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Conscientiousness.
D.	**MATERIALS:**	The results of the operations performed in 3.1.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

3.2.0 Review the technique for calculating area. (Mathematics 216)

3.2.1 Using the results of the operations performed, calculate the velocity of an object at various points in its motion.

3.2.2 Represent the instantaneous velocity of an object as a function of time ($s = f(t)$), using a graph.

3.2.3 Describe the motion of an object, from its graph.

3.2.4 Compare the rate of change (slope) in the position of an object in relation to time calculated in 3.1 with the value of its instantaneous speed.

3.2.5 Compare the area under the curve of velocity as a function of time with the change in the position of the object.

3.2.6 Compare their results with those of their classmates.

3.2.7 Discuss the usefulness of calculating the rate of change (slope) in analyzing a scientific phenomenon.

3.2.8 Discuss the usefulness of calculating the area under the curve of a graph when one is analyzing a scientific phenomenon.

3.2.9 Add the results of their work to the laboratory report begun in 3.1.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.3 Analyze the acceleration of an object in vertical motion, using results from an experiment.

PREREQUISITES:

3.2

RELATED CONTENT:

—	**SKILL:**	Interpreting data. (D-3)
—	**KNOWLEDGE:**	Graph of a = f (t), area under the curve a = f (t) as equivalent to ▲v, magnitude and direction of gravitational acceleration, mathematical formula a = ▲V/▲t. (A-5)
—	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, class discussion.

B.	**DURATION:**	150 minutes + homework.
C.	**EVALUATION:**	Quality of laboratory reports.
D.	**MATERIALS:**	The results of work done in 3.1 and 3.2, resource materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

3.3.1 Propose their own ideas about the acceleration of an object.

3.3.2 Compare their ideas with those of their classmates.

3.3.3 Suggest a mathematical relationship between the acceleration and velocity of an object, from the graph drawn in 3.2.

3.3.4 Compare their suggestions with those of their classmates, and select one for further study.

3.3.5 Verify the plausibility of the relationship selected, by using unit analysis.

3.3.6 Calculate the acceleration of the object at different points in time, from the results obtained in 3.2.

3.3.7 Represent the acceleration of the object as a function of time ($a = f(t)$), by means of a graph.

3.3.8 Describe the motion of the object, by means of graphs.

3.3.9 Compare the rate of change in the velocity of an object with the rate of acceleration.

3.3.10 Compare the area under the curve $a = f(t)$ with the change in the velocity of an object.

3.3.11 Compare their results with those of their classmates.

3.3.12 Discuss the error in calculating acceleration by this method.

3.3.13 Discuss the influence of the features of a moving object (mass and shape) on the rate of acceleration.

3.3.14 Complete the laboratory report begun in 3.1.

3.3.15 Become aware of the diversity of models of scientific knowledge by studying the correspondence between Beeckman and Descartes (17^{th} Century) concerning their ideas about the motion of bodies.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 3.4 Analyze the effect of height on the vertical motion of an object, after making observations.

PREREQUISITES:

3.3

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-1)
—	**KNOWLEDGE:**	Friction, aerodynamics of projectiles, terminal velocity, concept of gradient, wind tunnels. (A-10)
—	**ATTITUDE:**	Intellectual curiosity. (I-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, work in gymnasium or outdoors, simulation, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Quality of observations.
D.	**MATERIALS:**	Resource materials, timer, slide projector, stroboscope, camera, video camera (optional).
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Danger of falling objects.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

3.4.1 Observe the action of an object as it falls from a considerable height.

3.4.2 Formulate a hypothesis about the magnitude of the speed of the object observed.

3.4.3 Compare their hypotheses with those of their classmates, and select one for further study.

3.4.4 Verify with an experiment the hypothesis selected.

3.4.5 Compare the change in the velocity of the object in relation to time with the gravitational acceleration measured in 3.3. (Study the phenomenon of speed varying in relation to time by referring to the concept of gradient.)

3.4.6 Formulate a hypothesis about the cause of the difference that they observe.

3.4.7 Compare their hypotheses with those of their classmates.

3.4.8 Explain the reason for the shapes of objects used as projectiles, on the basis of what they have studied so far.

3.4.9 Learn about technical methods used to determine the ideal shape of objects that travel at high speed, using reference materials.

3.4.10 Using reference materials, evaluate the positive and negative effects on the environment resulting from the use of projectiles in atmospheric research, space research and military weaponry.

3.4.11 Write up short reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.5 Establish mathematical relationships linking various physical magnitudes characteristic of a moving object, on the basis of experimental results.

PREREQUISITES:

3.1, 3.2, 3.3

RELATED CONTENT:

–	**SKILL:**	Constructing a model. (E-2)
–	**KNOWLEDGE:**	Equations of Motion: $\vec{a} = \Delta\vec{v}/\Delta t \quad \vec{v} = \vec{v}_1 + \vec{a}\Delta t \quad \Delta s = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2$. (A-8)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Presentation, individual work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Willingness to interpret information.
D.	**MATERIALS:**	Resource materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-42, AV-43, AV-44
B-7, B-8, B-10
CS-11

LEARNING ACTIVITIES

THE STUDENTS:

3.5.1 Draw a velocity-time graph for a moving object accelerating uniformly.

3.5.2 Indicate on the graph the physical magnitudes characteristic of a moving object (initial velocity, final velocity, time interval, change in velocity).

3.5.3 Find a mathematical relationship between the co-ordinates of the velocity-time graph for the moving object, using specific values for the variables.

3.5.4 Find a mathematical relationship between the co-ordinates of the position-time graph for the moving object, using specific values for the variables.

3.5.5 Verify the plausibility of the mathematical relations determined above by means of unit analysis.

3.5.6 Discuss other mathematical relationships between the co-ordinates of motion of an object.

3.5.7 Compare the mathematical relationships discovered with the description of the phenomenon given by Galileo: "The spaces described by a body falling from rest with a uniformly accelerated motion are to each other as the squares of the time-intervals employed in traversing these distances."

3.5.8 Compare Galileo's concept of moving bodies with that of Descartes (17^{th} Century).

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.6 Analyze the rectilinear motion of objects in a plane, after doing experiments.

PREREQUISITES:

3.1, 3.2, 3.3, 3.5

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-1)
—	**KNOWLEDGE:**	Graphic analysis of rectilinear motion, calculation of displacement, velocity, acceleration. (A-7)
—	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, simulation, individual work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Calculation and graphic analysis techniques.
D.	**MATERIALS:**	Cart, spark timer or inkjet timer, air table, air track, camera, stroboscope, tachometer, inclined plane.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

CS-6, CS-21, CS-40, CS-41

LEARNING ACTIVITIES

THE STUDENTS:

3.6.1 Design a procedure for measuring the position, velocity and acceleration of an object in rectilinear motion accelerating uniformly.

3.6.2 Carry out their procedures.

3.6.3 Draw graphs of the position, velocity and acceleration of an object in relation to time.

3.6.4 Verify the relationships among the various graphic representations of the motion by calculating the rates of change and the areas under the curves.

3.6.5 Calculate the displacement and velocity of an object at different points in its trajectory.

3.6.6 Verify the plausibility of these calculations using unit analysis.

3.6.7 Compare the values calculated with the values represented by the graphs.

3.6.8 Become aware that uniform rectilinear motion is a phenomenon that may be treated as uniformly accelerated rectilinear motion where acceleration of the object is zero.

3.6.9 Write up reports of their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 3.7 Analyze the movement of a horizontally-launched projectile, after doing an experiment according to a suggested procedure.

PREREQUISITES:

3.6

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-5)
–	**KNOWLEDGE:**	Analysis the movement of a projectile into rectilinear movements, flight time, range and trajectory of a projectile. (A-7)
–	**ATTITUDE:**	Critical attitude. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, simulation, individual work, class discussion.

B.	**DURATION:**	200 minutes + homework.
C.	**EVALUATION:**	Quality of laboratory report.
D.	**MATERIALS:**	Camera, stroboscope, slide projector, projectile launcher, balls, air table, spark timer or inkjet timer, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-4, AV-5, AV-6, AV-38, AV-54
B-2, B-7, B-10, B-12
CS-19

LEARNING ACTIVITIES

THE STUDENTS:

3.7.1 Discuss the difference between the time that a horizontally-launched projectile might take to reach the ground and the time an object would take to fall from the same height.

3.7.2 Measure the physical magnitudes (position, speeds, accelerations, time) relevant for verifying the hypothesis selected.

3.7.3 Represent on a graph the vertical and horizontal accelerations of the projectile.

3.7.4 Represent on a graph the acceleration of a falling object.

3.7.5 Compare the vertical acceleration of two objects.

3.7.6 Compare their results with those of their classmates.

3.7.7 Describe the horizontal motion of a projectile, on the basis of their analysis of the graphs.

3.7.8 Describe the vertical motion of a projectile, on the basis of their analysis of the graphs.

3.7.9 Compare the vertical motion of a projectile with the motion of a falling object.

3.7.10 Advance their ideas about the range and flight time of a projectile.

3.7.11 Compare their ideas with those of their classmates.

3.7.12 Using resource materials, report on the social reasons that drew the Renaissance scholar Leonardo da Vinci to study ballistics.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 3.8 Analyze the motion of an obliquely-launched projectile, by doing an experiment and referring to material studied thus far.

PREREQUISITES:

3.6, 3.7

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-1)
—	**KNOWLEDGE:**	Maximum range of a projectile, components of a velocity vector. (A-10)
—	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, simulation, individual work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Quality of analyses.
D.	**MATERIALS:**	Camera, stroboscope, projectile, projectile launcher, slide projector, air table, spark timer or inkjet timer, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-4, AV-5, AV-6, AV-38
B-2, B-8, B-9, B-10, B-12
CS-13, CS-18, CS-19
M-24, M-35

LEARNING ACTIVITIES

THE STUDENTS:

3.8.1 Formulate hypotheses about the angle at which a projectile should be launched to attain maximum range.

3.8.2 Justify their hypotheses.

3.8.3 Design experimental procedures to verify their hypotheses.

3.8.4 Do their experiments in the laboratory.

3.8.5 Calculate the range of a projectile, using the mathematical relationships determined in 3.5.

3.8.6 Calculate the height that the projectile must attain for this range.

3.8.7 Compare the results of these calculations with the results of the measurements taken.

3.8.8 Distinguish the motion of a rocket from that of other projectiles.

3.8.9 Identify other fields of science and technology that benefit from the results of aerospace research and that improve the quality of life.

3.8.10 Illustrate with examples the connection between political priorities and the conquest of space.

3.8.11 Using reference materials, connect each of the following people to an important achievement in the exploration of space: the Montgolfier brothers, Arnauld, Giffard, Ader, Lilienthal, Zeppelin, the Wright brothers, Bell, Blériot, Lindberg, Coste and Bellonte, Whittle, Sikorsky, Yeager, Goddard, Brun, Gagarin, Glenn, Armstrong.

3.8.12 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

3.9 Use the knowledge they have acquired in their study of motion to solve problems and do numerical and graphic exercises.

PREREQUISITES:

3.1, 3.2, 3.3, 3.5, 3.6

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-1)
–	**KNOWLEDGE:**	Problem-solving techniques. (A-7)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, class discussion.

B.	**DURATION:**	Depending on number of answers to be verified.
C.	**EVALUATION:**	Methods of calculation and analysis.
D.	**MATERIALS:**	Calculator (optional), depending on the situations in the problems given.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

CS-19, CS-21, CS-22, CS-23, CS-31, CS-33, CS-40, CS-41, CS-42

LEARNING ACTIVITIES

THE STUDENTS:

3.9.1 Read each problem carefully, identifying the data needed to solve it.

3.9.2 Relate the appropriate units of measure to the physical quantities used in each problem.

3.9.3 Use mathematical operators correctly in solving problems.

3.9.4 Verify the plausibility of the answer using unit analysis.

3.9.5 Verify the plausibility of the answer by order of magnitude.

3.9.6 Verify the solution by means of an experiment or simulation, if necessary.

3.9.7 Propose the most elegant solution.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4 Analyze the rectilinear motion of objects to which forces are applied, on the basis of results obtained in laboratory experiments.

4.1 Identify, after making observations, the cause of changes in the state of rest or state of motion of an object.

PREREQUISITES:

2, 3.6

RELATED CONTENT:

—	**SKILL:**	Recognizing a problem. (C-1)
—	**KNOWLEDGE:**	Cause of motion, cause of changes in motion, inertia, direction of forces. (A-2)
—	**ATTITUDE:**	Intellectual curiosity. (I-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, simulation, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Perceptiveness in recognition of problems.
D.	**MATERIALS:**	Carts, cord, table on wheels, wood block, elastics, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Danger of collisions and falls.

SUGGESTED REFERENCES:

AV-40, AV-43, AV-44
B-2, B-3
CS-26, CS-27, CS-32, CS-34

LEARNING ACTIVITIES

THE STUDENTS:

4.1.1 List methods of setting an object in motion.

4.1.2 Compare their lists with those of their classmates, and select some methods for further study.

4.1.3 Verify the methods selected, by means of experiments.

4.1.4 After making observations, identify the forces acting on objects they set in motion.

4.1.5 Formulate a hypothesis about the nature of the force that resists the movement of objects.

4.1.6 Compare their hypotheses with those of their classmates.

4.1.7 List the methods of inducing variation in the motion of an object.

4.1.8 Discuss the methods listed with their classmates.

4.1.9 Illustrate the direction of forces that alter the motion of objects, using diagrams.

4.1.10 Describe the relation between the direction of forces applied to a moving object and the direction of a moving object.

4.1.11 Associate inertia with the tendency of objects to conserve their state of rectilinear uniform movement or their state of rest.

4.1.12 Compare Aristotle's concepts of dynamics (the nature of motion in a medium) with Galileo's concepts of motion, using reference materials.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.2 Do experiments in which they measure the acceleration of objects of different mass to which force is applied.

PREREQUISITES:

2.2, 4.1

RELATED CONTENT:

–	**SKILL:**	Observing. (B-2)
–	**KNOWLEDGE:**	Effect of mass and force on the acceleration of an object. (A-5)
–	**ATTITUDE:**	Critical attitude. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, simulation, individual work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Quality of descriptions.
D.	**MATERIALS:**	Cart, elastics, spring balances (dynamometers), spark timer or inkjet timer, air table, sets of graduated weights.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-39
CS-28, CS-34

LEARNING ACTIVITIES

THE STUDENTS:

4.2.1 Predict how acceleration will be affected by forces applied to objects of different masses in their direction of motion.

4.2.2 Compare their predictions with those of their classmates, and select some for further study.

4.2.3 Design a procedure for an experiment to verify the predictions selected.

4.2.4 Compile, in a table prepared by the group, the results obtained for different forces and objects of different mass.

4.2.5 Represent the results by means of graphs.

4.2.6 Discuss the motion of objects, referring to these graphs.

4.2.7 Write up a summary of everyone's work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.3 Define a mathematical relationship linking the various factors that affect the acceleration of an object, using experimental data.

PREREQUISITES:

4.2

RELATED CONTENT:

–	**SKILL:**	Constructing a model. (E-6)
–	**KNOWLEDGE:**	Newton's Second Law: a = F/m. (A-8)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Individual work, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Quality of arguments.
D.	**MATERIALS:**	Resource materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-75, AV-76
B-17, B-35
CS-27

LEARNING ACTIVITIES

THE STUDENTS:

4.3.1 Propose a mathematical relationship linking the force applied to an object, the acceleration and the mass of the object, on the basis of what they have already studied.

4.3.2 Compare their propositions with those of their classmates.

4.3.3 Derive a unit that is equivalent to a newton, using unit analysis.

4.3.4 Discuss the influence of Isaac Newton's studies of movement (17^{th} Century) on the people of his time.

4.3.5 Describe the influence of Voltaire (18^{th} Century) in making Newton's work widely known.

4.3.6 Demonstrate how the work of Leibniz, Galileo and Kepler in the 17^{th} Century, and Brahe and Copernicus in the 16^{th} Century, influenced Newton's construction of a model of the mechanism of the universe.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.4 Appreciate that bodies fall because of weight, using knowledge they have acquired in various disciplines.

PREREQUISITES:

4.3

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-1)
—	**KNOWLEDGE:**	Concepts of mass and weight, weight of an object ($F_g = mg$). (A-1)
—	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, demonstration, simulation, class discussion.

B.	**DURATION:**	75 minutes.
C.	**EVALUATION:**	Ability to integrate knowledge.
D.	**MATERIALS:**	Objects of different mass and shape, experimental results obtained in 3.3, scale, spring balance (dynamometer).
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-41, AV-46
B-36
CS-35, CS-42
M-43

LEARNING ACTIVITIES

THE STUDENTS:

4.4.0 Review the description of Earth. (Geography 114)

Review the behaviour of distant electrical charges. (Physical Sciences 416-436)

Review the effect of distancing a magnet on the intensity of its magnetic field. (Physical Sciences 416-436)

4.4.1 Formulate hypotheses about the nature of the force that accelerates a falling object, on the basis of their observations.

4.4.2 Discuss their hypotheses with their classmates.

4.4.3 Measure the mass of an object used in 3.1.

4.4.4 Determine the magnitude of the force that accelerates an object, using the experimental data obtained in 3.3 and the mathematical relationship discovered in 4.3.

4.4.5 Comprehend that weight is the cause of gravitational acceleration.

4.4.6 Observe objects of different shape and mass in vertical motion.

4.4.7 Discuss the effect of friction on moving objects of different mass and shape.

4.4.8 Predict the magnitude of gravitational force acting on an object distant from the Earth, on the basis of their geographical knowledge.

4.4.9 Discuss their predictions with their classmates.

4.4.10 Formulate a hypothesis about the magnitude of gravitational forces acting on other planets.

4.4.11 Distinguish the concept of mass from that of weight.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 4.5 Analyze the variables associated with a moving object that receives an impulse, by solving problems that draw on their knowledge of forces.

PREREQUISITES:

2, 3.1, 3.2, 3.3, 4.3, 4.4

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-2)
—	**KNOWLEDGE:**	Impulse, variation of quantity of motion. (A-3)
—	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, simulation, class discussion.

B.	**DURATION:**	150 minutes + homework.
C.	**EVALUATION:**	Ability to apply knowledge to new problems.
D.	**MATERIALS:**	Carts, air table, spark timer or inkjet timer, slide projector, stroboscope, camera, video camera (optional), resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-17, AV-39
B-5
CS-8, CS-41
M-11

LEARNING ACTIVITIES

THE STUDENTS:

4.5.1 Consider the different meanings of the word "impulse".

4.5.2 Find the meaning of the term "impulse" as it is used in physics.

4.5.3 Discuss with their classmates the effect of an impulse on an object at rest or in motion.

4.5.4 Demonstrate that the mathematical representation of an object receiving an impulse is only another way of representing the mathematical equation $a = F/m$ that they derived in 4.3.

4.5.5 Design an experimental procedure to measure quantitative variation in the motion of an object receiving an impulse in the direction of its motion.

4.5.6 Carry out their procedure.

4.5.7 Demonstrate that the change in velocity of an object is a product of the force exerted on it.

4.5.8 Demonstrate, on the basis of observations in the environment or the laboratory, that change in the direction of motion of an object depends on the magnitude and direction of the force exerted on it.

4.5.9 Connect rocket propulsion with the concepts of action/reaction and of the conservation of quantity of motion.

4.5.10 List the advantages and disadvantages of using different propellants in modern systems of rocket propulsion.

4.5.11 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.6 Identify factors that influence the magnitude of frictional force, on the basis of observations in the environment or in the laboratory.

PREREQUISITES:

2, 4.3, 4.4

RELATED CONTENT:

–	**SKILL:**	Observing. (B-2)
–	**KNOWLEDGE:**	Factors influencing the magnitude of frictional force. (A-1)
–	**ATTITUDE:**	Objectivity. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, simulation, individual work, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Quality of observations.
D.	**MATERIALS:**	Resource materials, inclined plane, wood blocks of different masses and sizes, pulley, cord, sets of graduated weights, lubricants, velcro, teflon.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-52, AV-55
B-8, B-11

LEARNING ACTIVITIES

THE STUDENTS:

4.6.1 Predict factors that influence the magnitude of frictional force.

4.6.2 Compare their predictions with those of their classmates, and select some for further study.

4.6.3 Verify selected predictions by means of an experiment carried out according to a suggested procedure.

4.6.4 Discuss with their classmates methods of reducing the negative effect of friction on moving objects.

4.6.5 Verify the effectiveness of the methods proposed, in experiments.

4.6.6 Compile the results in a table prepared by the group.

4.6.7 Discuss ways of increasing or decreasing friction, using example such as tires or shoes.

4.6.8 Discuss how friction affects the movement of objects in the environment.

4.6.9 List the ways in which animals make effective use of friction to move about.

4.6.10 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 4.7 Determine the coefficient of friction for two surfaces, on the basis of an experiment.

PREREQUISITES:

4.6

RELATED CONTENT:

–	**SKILL:**	Measuring. (G-2)
–	**KNOWLEDGE:**	Normal force, coefficient of friction, $\mu = F_f / F_n$, starting friction, sliding friction. (A-3)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Quality of measuring techniques.
D.	**MATERIALS:**	Resource materials, inclined plane, wood blocks, metal and plastic blocks, plates made of wood, metal, plastic, glass; leather, rubber, pulley, cord, sets of graduated weights, lubricators, velcro, teflon.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-52, AV-55
B-8

LEARNING ACTIVITIES

THE STUDENTS:

4.7.0 Review the concept of normal. (Module 1, 2.3)

4.7.1 Represent with vectors the components of forces exerted on an object at rest on a surface.

4.7.2 Measure the magnitude of the force of friction between the object and the surface, by doing an experiment according to a suggested procedure.

4.7.3 Justify the plausibility of their measurements by order of magnitude.

4.7.4 Calculate the ratio of the magnitude of frictional force to the magnitude of normal force exerted by the surface, on the basis of these measurements.

4.7.5 Compile these results in a table prepared by the group.

4.7.6 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

4.8 Use their knowledge of forces to solve problems, do numerical exercises and draw graphs.

PREREQUISITES:

4.1, 4.2, 4.3, 4.4, 4.6

RELATED CONTENT:

—	**SKILL:**	Interpreting data. (D-1)
—	**KNOWLEDGE:**	Graphic analysis of rectilinear movement, calculation of acceleration and forces of friction, numerical applications of Newton's second law, calculation of weight (F_g = mg). (A-7)
—	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, simulation, individual work, class discussion.

B.	**DURATION:**	150 minutes + homework.
C.	**EVALUATION:**	Calculation and graphic analysis techniques.
D.	**MATERIALS:**	Calculator (optional), depending on the problems suggested.
E.	**SAFETY MEASURES:**	Depending on solutions to be verified.

SUGGESTED REFERENCES:

AV-71, AV-79
CS-26, CS-27, CS-28, CS-34, CS-35, CS-42

LEARNING ACTIVITIES

THE STUDENTS:

4.8.1 Read each problem carefully, identifying the data needed to solve it.

4.8.2 Relate the appropriate units of measure to the physical quantities used in each problem.

4.8.3 Use mathematical operators correctly in solving problems.

4.8.4 Verify the plausibility of the answer, using unit analysis.

4.8.5 Verify the plausibility of the answer by order of magnitude.

4.8.6 Verify the solution by means of an experiment or simulation, if necessary.

4.8.7 Propose the most elegant solution.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5 **Select a simple machine to perform a task, on the basis of specific qualities that they have analyzed in the laboratory.**

5.1 Identify simple machines and systems composed of simple machines in the environment.

PREREQUISITES:

RELATED CONTENT:

–	**SKILL:**	Observing. (B-1)
–	**KNOWLEDGE:**	Use of simple machines (lever, pulley, wheel and axle, inclined plane or wedge, screw), components of simple machines (crank, lever, pulley block, drum), power, fulcrum, counterforce. (A-1)
–	**ATTITUDE:**	Intellectual curiosity. (I-4)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, individual work, outing, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Quality of descriptions.
D.	**MATERIALS:**	Various simple machines (pliers, nutcrackers, tweezers, jack, wheelbarrow), resource materials.
E.	**SAFETY MEASURES:**	Usual safety rules during an outing.

SUGGESTED REFERENCES:

AV-53
B-20, B-21, B-22
M-52

LEARNING ACTIVITIES

THE STUDENTS:

5.1.0 Review the first theme in the program Introduction to Technology 314 - "Technology in the Life of Man."

5.1.1 Describe, from memory, simple machines that they use.

5.1.2 Draw diagrams of the simple machines described.

5.1.3 By means of vectors and straight lines, indicate on the diagrams the physical magnitudes involved in the use of these machines.

5.1.4 List the uses of simple machines or systems composed of simple machines in their daily lives.

5.1.5 Identify one or more of the five simple machines used in these systems.

5.1.6 Illustrate the function of these machines, using diagrams.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.2 Describe the work performed by a simple machine in moving an object, using effort, effort distance, resistance, resistance distance.

PREREQUISITES:

1.6, 2.2, 2.3, 4.1, 4.6, 5.1

RELATED CONTENT:

–	**SKILL:**	Formulating generalizations. (B-2)
–	**KNOWLEDGE:**	Nature of mechanical work, units of measure for mechanical work. (A-2)
–	**ATTITUDE:**	Critical attitude. (H-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, class discussion.

B.	**DURATION:**	125 minutes.
C.	**EVALUATION:**	Quality of interpretations.
D.	**MATERIALS:**	Horizontal gymnastics bar, pulleys, cord, levers, inclined plane, winches, cranks, carts, sets of graduated weights, spring balances (dynamometers), universal supports, C-clamps, heavy objects.
E.	**SAFETY MEASURES:**	Danger of falling objects or excessive effort.

SUGGESTED REFERENCES:

CS-30, CS-48

LEARNING ACTIVITIES

THE STUDENTS:

5.2.0 Review the unit of energy (joule). (Human Biology 314)

Review the concept of the mechanical advantage of simple machines. (Introduction to Technology 314)

5.2.1 Estimate the magnitude of the force they must employ to raise themselves on the horizontal bar.

5.2.2 Compare their estimations with those of their classmates.

5.2.3 Formulate a hypothesis about the variables related to the muscular effort they must exert to raise themselves to different heights.

5.2.4 Verify their hypotheses by means of experiments.

5.2.5 Discuss their observations with their classmates.

5.2.6 Propose diagrams of machine structures capable of moving an object from a given height.

5.2.7 Formulate a hypothesis about the magnitude of the force and the magnitude of displacement of the force involved in moving the object.

5.2.8 Justify their hypotheses.

5.2.9 Verify their hypotheses by means of experiments.

5.2.10 Compare their results with the hypothesis formulated.

5.2.11 Relate the muscular effort they have made to raise themselves on the bar to the mechanical work produced by a machine.

5.2.12 Suggest a mathematical relationship linking the variables involved in mechanical work.

5.2.14 Relate mechanical work to energy transformation.

5.2.15 Find a unit of work equivalent to the joule (J), using unit analysis.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.3 Justify the selection of a simple machine to do a particular type of work, on the basis of the results of an experiment.

PREREQUISITES:

5.2

RELATED CONTENT:

–	**SKILL:**	Organizing data. (G-2)
–	**KNOWLEDGE:**	Efficiency. (A-3)
–	**ATTITUDE:**	Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Quality of verification methods.
D.	**MATERIALS:**	Pulleys, cord, cranks, inclined plane, winches, levers, sets of graduated weights, spring balances (dynamometers), universal supports, carts, lubricants, C-clamps, heavy objects.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-51, AV-52, AV-53
M-52

LEARNING ACTIVITIES

THE STUDENTS:

5.3.1 Propose their conception of the efficiency of a machine.

5.3.2 Compare their conceptions with those of their classmates, and select some for further study.

5.3.3 Determine the efficiency of the machines used in 5.2, using the selected proposals.

5.3.4 Estimate the energy loss on the basis of the efficiency of these machines.

5.3.5 Propose improvements that would increase the efficiency of the machines used.

5.3.6 Verify their propositions by means of experiments.

5.3.7 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.4 Justify the selection of a simple machine to perform a specific task in a given time, after doing an experimental study.

PREREQUISITES:

3.2, 5.3

RELATED CONTENT:

–	**SKILL:**	Formulating generalizations. (F-2)
–	**KNOWLEDGE:**	Mechanical power, unit of measure for power, rate of energy transfer. (A-2)
–	**ATTITUDE:**	Critical attitude. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	75 minutes + homework.
C.	**EVALUATION:**	Quality of methods proposed.
D.	**MATERIALS:**	Pulleys, cord, cranks, inclined plane, winches, levers, sets of graduated weights, spring balances (dynamometers), universal supports, carts, lubricants, C-clamps, heavy objects.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-39

LEARNING ACTIVITIES

THE STUDENTS:

5.4.0 Review the concept of electric power. (Physical Sciences 416-436)

5.4.1 Propose their ideas about the power of a machine.

5.4.2 Compare their ideas with those of their classmates.

5.4.3 Relate the power of a machine to the rate of energy conversion.

5.4.4 Propose a mathematical relationship linking the variables involved in calculating mechanical power.

5.4.5 Discuss their propositions with their classmates, and select one for further study.

5.4.6 Find a unit equivalent to the watt, by applying unit analysis to the mathematical relationship selected.

5.4.7 Learn about units of power equivalent to the watt, using reference materials.

5.4.8 Calculate the power of the simple machines used in 5.3.

5.4.9 Identify ways of increasing the power of simple machines.

5.4.10 Verify the above by means of experiments.

5.4.11 Demonstrate that the mechanical power of a machine is a function of the speed with which it displaces the force of resistance. ($P = Fv$).

5.4.12 Complete the reports on their work begun in 5.3.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

5.5 Use their knowledge of mechanical work to solve problems, do numerical exercises and draw graphs related to simple machines.

PREREQUISITES:

5.1, 5.2, 5.3, 5.4

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-1)
—	**KNOWLEDGE:**	Practical and numerical applications of concepts of mechanical work, mechanical power, and efficiency of simple machines. (A-7)
—	**ATTITUDE:**	Intellectual curiosity. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, simulation, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Calculation and graphic analysis techniques.
D.	**MATERIALS:**	Pulleys, cord, cranks, inclined plane, winches, levers, sets of graduated weights, spring balances (dynamometers), universal supports, carts, lubricants, C-clamps, heavy objects, calculator (optional).
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

CS-29, CS-42

LEARNING ACTIVITIES

THE STUDENTS:

5.5.1 Read each problem carefully, identifying the data needed to solve it.

5.5.2 Relate the appropriate units of measure to the physical quantities used in each problem.

5.5.3 Use mathematical operators correctly in solving problems.

5.5.4 Verify the plausibility of the answer using unit analysis.

5.5.5 Verify the plausibility of the answer by order of magnitude.

5.5.6 Verify the solution by means of an experiment or simulation, if necessary.

5.5.7 Propose the most elegant solution.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 5.6 Demonstrate that the invention and development of simple machines corresponds to a human need, using examples from the history of science and technology.

PREREQUISITES:

5.4

RELATED CONTENT:

–	**SKILL:**	Formulating generalizations. (F-2)
–	**KNOWLEDGE:**	Reasons for the development of machines throughout history. (A-5)
–	**ATTITUDE:**	"Constructivist" view of science. (I-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, industrial visit, class discussion.

B.	**DURATION:**	75 minutes + free time + homework
C.	**EVALUATION:**	Quality of interpretations.
D.	**MATERIALS:**	Resource materials.
E.	**SAFETY MEASURES:**	Usual safety rules during visits.

SUGGESTED REFERENCES:

AV-64
B-17, B-19, B-20, B-21
M-35, M-52

LEARNING ACTIVITIES

THE STUDENTS:

5.6.0 Review events in the history of science and technology. (General History 214, History of Québec and Canada 314, Introduction to Technology 314)

5.6.1 Using reference materials, describe the works of early scientists who contributed to the development of machines: Chersiphron and Metagenos (6th Century, B.C.), Archytas (6th Century B.C.), Archimedes (3rd Century B.C.), Leonardo da Vinci (15th and 16th Centuries), William Lee (16th Century), Pascal (17th Century).

5.6.2 Recount events that influenced research in the development of machines.

5.6.3 Relate the present uses of composite machines to the historical events that they have described.

5.6.4 Describe how particular civilizations have influenced the development of machines throughout history.

5.6.5 Describe how the development of machines influenced civilizations throughout history.

5.6.6 During a visit to an industry, understand that machines are developed in order to increase productivity and make people's work easier.

5.6.7 List the ways in which the development of machines has increased or decreased the quality of human life.

5.6.8 List the ways in which the development of machines has benefited or harmed the environment (mines, forests, waterways).

5.6.9 Discuss the possibility and consequences of machines surpassing humans (cf. science fiction films such as *Metropolis*, *Robots*).

5.6.10 Comment on one of the following quotations:

"Human beings will have increasingly more expectations of machines to help them forget about other machines, and perhaps the hallmark of the civilized person will one day be to live a completely fictionalized life." Phillipe Sollers, (b. 1936).

"The machine frees human beings to devote greater attention to humanity." Jean Fourastié, (b. 1907).

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

6 **Demonstrate that work is produced with every transformation of mechanical energy.**

6.1 Relate mechanical work to the potential gravitational energy acquired by an object.

PREREQUISITES:

1.6, 2.1, 5.2

RELATED CONTENT:

–	**SKILL:**	Constructing a model. (E-2)
–	**KNOWLEDGE:**	Nature of potential gravitational energy. (A-11)
–	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, demonstrations, presentations, individual work, class discussion.

B.	**DURATION:**	100 minutes.
C.	**EVALUATION:**	Ability to integrate knowledge.
D.	**MATERIALS:**	Depending on demonstrations, resource materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

AV-45, AV-47, AV-49, AV-77
B-11, B-14

LEARNING ACTIVITIES

THE STUDENTS:

6.1.0 Review the ways of producing electrical energy. (Physical Sciences 416-436)

6.1.1 Propose their own ideas of potential gravitational energy.

6.1.2 Compare their ideas with those of their classmates.

6.1.3 List the mechanical systems in their environment that use or generate potential gravitational energy.

6.1.4 Demonstrate that an object's potential gravitational energy equals the work done to move the object to the position it occupies.

6.1.5 Demonstrate that the potential gravitational energy of an object depends on its weight and its position.

6.1.6 Demonstrate that the basic units for describing work are identical to the basic units that describe potential gravitational energy.

6.1.7 Support their demonstration in front of their classmates.

6.1.8 Relate the hydroelectric energy produced in power plants to potential gravitational energy.

6.1.9 Illustrate examples of natural phenomena, drawn from the environment, involving potential gravitational energy.

6.1.10 Show, with examples drawn from the history of technology, that the first machines were invented mainly to conquer gravity (the inclined plane, screw, water wheel).

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

6.2 Describe the energy of a moving object, as analyzed in the laboratory after an experiment.

PREREQUISITES:

3.2, 5.2

RELATED CONTENT:

—	**SKILL:**	Constructing a model. (E-2)
—	**KNOWLEDGE:**	Nature of kinetic energy. (A-3)
—	**ATTITUDE:**	Willingness to compare ideas. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	150 minutes + homework.
C.	**EVALUATION:**	Quality of proposed mathematical models.
D.	**MATERIALS:**	Inclined plane, cart, air table, air track, spark timer or inkjet timer, pulley, cord, sets of graduated weights, tape, ruler.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-48, AV-61, AV-77
CS-30

LEARNING ACTIVITIES

THE STUDENTS:

6.2.1 For a particular displacement, determine the work performed by various forces applied to an object.

6.2.2 Measure the change in velocity of the object for the displacement selected and for each force applied.

6.2.3 Draw a graph of the work performed on the object as a function of the speed it has attained.

6.2.4 Using the graph, suggest a mathematical relationship between the work performed on the object and the speed it has attained.

6.2.5 Relate the work performed by the forces to the kinetic energy acquired by the object.

6.2.6 Deduce the mathematical ratio of the kinetic energy acquired by an object and its speed.

6.2.7 Draw graphs of the mathematical ratio deduced.

6.2.8 Find the constant of proportionality of the mathematical ratio represented, by calculating the rate of change (slope of the curve).

6.2.9 Compare the results of their calculations with one of the physical values used during the experiment.

6.2.10 Discuss with their classmates the discrepancy between the calculated value and the physical value used.

6.2.11 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 6.3 Relate mechanical work to the potential energy acquired by an elastic object.

PREREQUISITES:

2.4, 5.2

RELATED CONTENT:

- **SKILL:** Constructing a model. (E-2)
- **KNOWLEDGE:** Nature of potential elastic energy. (A-11)
- **ATTITUDE:** Willingness to synthesize and apply knowledge. (F-2)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, laboratory work, individual work, class discussion.

B. DURATION: 100 minutes + homework.

C. EVALUATION: Quality of mathematical models proposed.

D. MATERIALS: Hooke's law apparatus, elastic band, ball, balloon, bow, racquet, sets of graduated weights.

E. SAFETY MEASURES: Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

6.3.0 Review the uses of elastic objects used in sporting activities. (Physical Education 112, 212, 312, 412 and 512)

6.3.1 List objects in their environment that they use for their elastic properties.

6.3.2 Design a procedure for measuring the deformation of an elastic object (bow, ball, balloon, exercise spring).

6.3.3 Draw a graph of the deformation of an object as a function of applied force.

6.3.4 Determine the value of the spring constant, using the knowledge acquired in 2.4.

6.3.5 Determine the work performed on the object, by calculating the area without the curve.

6.3.6 Relate the value determined to the potential energy stored by the object.

6.3.7 Propose a mathematical relationship between potential energy stored by the object and its deformation.

6.3.8 Compare their propositions with those of their classmates, and select one for further study.

6.3.9 Verify, by means of unit analysis, the proposition selected.

6.3.10 Using skills and knowledge acquired during the experiment, select the elastic object that performs best in its category (bow, balloon, racquet).

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

6.4 Analyze a transformation of mechanical energy, using measurements and calculations.

PREREQUISITES:

3.2, 5.2, 6.1, 6.2

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-1)
—	**KNOWLEDGE:**	Law of conservation of energy. (A-8)
—	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	150 minutes + homework.
C.	**EVALUATION:**	Quality of interpretation.
D.	**MATERIALS:**	Pendulums, carts, bricks, springs, spark timer or inkjet timer, inclined plane, pulleys, levers, cord, recording tape, marbles, sets of graduated weights.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment. Care in using high voltages.

SUGGESTED REFERENCES:

AV-37, AV-61, AV-77
B-2, B-3
CS-33, CS-42
M-7, M-52

LEARNING ACTIVITIES

THE STUDENTS:

6.4.0 Review the law of the conservation of energy. (Physical Sciences 416-436)

Review the concept of the perpetual transformation of energy. (Physical Sciences 416-436)

6.4.1 By carrying out an experimental procedure that they have designed, determine the difference (tolerance) between the quantities of energy predicted and the quantities of energy measured during a transformation of potential energy into kinetic energy.

6.4.2 Relate the loss of energy determined in 6.4.1 to mechanical work produced by forces of friction.

6.4.3 Determine the quantity of mechanical energy released during the transformation.

6.4.4 State a property of energy that explains the facts observed during the transformation of one form of mechanical energy into another.

6.4.5 Discuss their statements with their classmates, and select one for further study.

6.4.6 Compare the selected statement with the concept of energy proposed by the English mathematician, physicist and Egyptologist Thomas Young (18th and 19th Centuries).

6.4.7 Using reference materials, learn that scientists' present concept of energy derives from the substitution of the term "energy" for the term "life force" by Thomas Young in 1807.

6.4.8 Distinguish mechanical energy from a mechanical energy system.

6.4.9 Write up reports on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

6.5 Relate mechanical work to the rise in temperature produced in a transformation of energy, after performing an experiment according to a suggested procedure.

PREREQUISITES:

5.2, 6.4

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-2)
—	**KNOWLEDGE:**	Thermal energy released in a mechanical transformation. (A-10)
—	**ATTITUDE:**	Willingness to synthesize and apply knowledge. (F-2)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, laboratory work, individual work, class discussion.

B.	**DURATION:**	75 minutes + homework.
C.	**EVALUATION:**	Quality of interpretation.
D.	**MATERIALS:**	Heat tube, marbles, thermometer, rubber stopper with hole, resource materials.
E.	**SAFETY MEASURES:**	Precautions in handling laboratory materials and equipment.

SUGGESTED REFERENCES:

AV-39, AV-77
B-5, B-6

LEARNING ACTIVITIES

THE STUDENTS:

6.5.0 Review the concept of thermal energy. (Physical Sciences 416-436)

6.5.1 Measure the temperature increase in a transformation of mechanical energy, during an experiment done according to a suggested procedure.

6.5.2 Compare their results with those of their classmates.

6.5.3 Relate the heat produced during the course of the experiment to work produced by forces of friction.

6.5.4 Differentiate the concept of heat from that of thermal energy.

6.5.5 Using reference materials, learn about James Prescott Joule's work in the field of thermodynamics (19^{th} Century).

6.5.6 Using reference materials, learn about the work of Sadi Carnot (19^{th} Century) on the equivalence of the concept of heat and the concept of work.

6.5.7 Demonstrate that a new idea may be rejected by the scientific community of the time, though it may later prove to be correct, by referring to the controversy that surrounded the writings of Sadi Carnot on heat, work and energy: "Reflections on the Motive Power of Fire and Its Means of Development."

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 6.6 Compare the energy output of various mechanical systems used to perform a task.

PREREQUISITES:

6.4, 6.5

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-1)
—	**KNOWLEDGE:**	Energy output of mechanical systems, sources of energy. (A-10)
—	**ATTITUDE:**	Objectivity. (F-1)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, individual work, class discussion.

B.	**DURATION:**	75 minutes.
C.	**EVALUATION:**	Quality of the argument.
D.	**MATERIALS:**	Resource materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

6.6.1 List mechanical systems used in their environment.

6.6.2 Relate each of these systems to an energy source that powers it.

6.6.3 Compare the amounts of energy produced by each of the systems listed, using reference materials.

6.6.4 Explain, in terms of energy output, the choice of a particular mechanical system to perform a task.

6.6.5 Discuss the relevance of selecting mechanical systems to perform tasks under particular conditions (climate, energy resources, natural environment, technological resources).

6.6.6 Discuss, in light of environmental concerns, the value of arguments citing profitability and efficiency when used to support any technological project.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

6.7 Use their knowledge about work and mechanical energy to solve problems, do numerical exercises and draw graphs related to energy transformations.

PREREQUISITES:

6.1, 6.2, 6.4, 6.5

RELATED CONTENT:

–	**SKILL:**	Interpreting data. (D-1)
–	**KNOWLEDGE:**	Numerical and graphic applications of mechanical energy transformations. (A-7)
–	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, laboratory work, simulation, class discussion.

B.	**DURATION:**	100 minutes + homework.
C.	**EVALUATION:**	Calculation and graph analysis techniques.
D.	**MATERIALS:**	Calculator (optional), depending on the problems to be done.
E.	**SAFETY MEASURES:**	Depending on solutions to be verified.

SUGGESTED REFERENCES:

CS-30, CS-33, CS-42

LEARNING ACTIVITIES

THE STUDENTS:

6.7.1 Read each problem carefully, identifying the data needed to solve it.

6.7.2 Relate the appropriate units of measure to the physical quantities used in each problem.

6.7.3 Use mathematical operators correctly in solving problems.

6.7.4 Verify the plausibility of the answer using unit analysis.

6.7.5 Verify the plausibility of the answer by order of magnitude.

6.7.6 Verify the solution by means of an experiment or simulation, if necessary.

6.7.7 Propose the most elegant solution.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

7 Identify the consequences for science, technology, society and the environment of developing and using our knowledge of motion, by doing an impact study.

7.1 Appreciate how the development and use of knowledge regarding motion have affected societies throughout history, using resource materials.

PREREQUISITES:

RELATED CONTENT:

—	**SKILL:**	Interpreting data. (D-4)
—	**KNOWLEDGE:**	Development of scientific knowledge regarding motion (transport, communication). (A-1)
—	**ATTITUDE:**	"Constructivist" view of science. (I-3)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, individual work, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Quality of interpretations.
D.	**MATERIALS:**	Resource materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

B-16, B-21, B-32, B-34
M-3, M-4, M-5, M-6, M-10, M-11, M-32, M-35, M-44, M-52

LEARNING ACTIVITIES

THE STUDENTS:

7.1.0 Review concepts in the history of science and technology. (General History 214, Introduction to Technology 314, History of Québec and Canada 414)

7.1.1 List the works of philosophers of antiquity who paved the way for the development of scientific knowledge regarding motion.

7.1.2 Using reference materials, recount the work of scientists who contributed to the development of scientific knowledge regarding motion (Aristotle, Kepler, Galileo, Beeckman, Descartes, Leibniz, Newton, Einstein).

7.1.3 Establish a connection between the trial and conviction of Galileo and Descartes' refusal to publish his treatise *The World*.

7.1.4 Demonstrate how the speed of transport and communication has evolved throughout history, using a graph.

7.1.5 Imagine future technological applications related to motion.

7.1.6 Describe how developments in the knowledge of motion have influenced the arts (literature, music, painting, sculpture) throughout history.

7.1.7 Write accounts of their research for a compendium of information to which the whole class contributes.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 7.2 Appreciate how the development and use of knowledge regarding motion affect the quality of life, after making observations and consulting resource materials.

PREREQUISITES:

7.1

RELATED CONTENT:

—	**SKILL:**	Formulating generalizations. (F-1)
—	**KNOWLEDGE:**	Repercussions on quality of life of developing the technology of motion (health, comfort, access to consumer goods). (A-1)
—	**ATTITUDE:**	Sense of belonging.

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, individual work, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Quality of predictions.
D.	**MATERIALS:**	Resource materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

7.2.1 List applications of the technology of motion which have influenced the quality of life during the course of history.

7.2.2 Classify the technological applications listed according to their advantages and disadvantages.

7.2.3 Predict the effects of future technological discoveries about motion on the quality of life.

7.2.4 Write short papers on their work.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

7.3 Appreciate how the development and use of knowledge regarding motion affect the natural and artificial environments, using observations and reference materials.

PREREQUISITES:

7.1

RELATED CONTENT:

—	**SKILL:**	Organizing Data. (D-1)
—	**KNOWLEDGE:**	Effects on the environment of developing technical applications of motion (pollution, waste of resources, quick intervention during natural disasters). (A-1)
—	**ATTITUDE:**	Sense of responsibility (environment). (H-7)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Brainstorming, group work, individual work, outing, class discussion.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Quality of methods proposed.
D.	**MATERIALS:**	Resource materials.
E.	**SAFETY MEASURES:**	Usual safety rules during an outing.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

7.3.1 List technological applications of motion that affect the environment.

7.3.2 Classify the applications listed according to their advantages and disadvantages.

7.3.3 Propose methods for reducing the negative effects of technologies deemed harmful to the environment.

7.3.4 Estimate the feasibility of the methods proposed.

7.3.5 Predict how future technological applications of motion will affect the environment.

7.3.6 Write accounts of their research for a compendium of information to which the whole class contributes.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 7.4 Demonstrate the role played by Québec in research and development related to the mechanics of motion, using reference materials.

PREREQUISITES:

RELATED CONTENT:

–	**SKILL:**	Recognizing a problem. (C-1)
–	**KNOWLEDGE:**	Organzations involved in mechanics research in Québec, products of mechanics research that are manufactured in Québec, social and economic effects.
–	**ATTITUDE:**	Sense of belonging. (H-7)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Individual work, group work, class discussion.

B.	**DURATION:**	75 minutes + homework.
C.	**EVALUATION:**	Quality of communication.
D.	**MATERIALS:**	Resource materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

7.4.1 List examples of state-of-the-art research in mechanics currently being done in the world, using reference materials.

7.4.2 Identify which of these research projects are being done in Québec.

7.4.3 Name companies and institutions in Québec that cooperate in the development of mechanics.

7.4.4 Describe at least one project or piece of research dealing with mechanics that has been undertaken by a Québec company or institution.

7.4.5 Write accounts of their research for a compendium of information to which the whole class contributes.

TEACHER'S NOTES:

SPECIFIC OBJECTIVES
(terminal and intermediate)

THE STUDENTS WILL LEARN HOW TO:

** 7.5 Identify professions associated with the mechanics of motion, using reference materials.

PREREQUISITES:

RELATED CONTENT:

–	**SKILL:**	Formulating generalizations. (F-2)
–	**KNOWLEDGE:**	Professions associated with mechanics. (A-6)
–	**ATTITUDE:**	Fascination with science. (H-6)

SUGGESTED TEACHING PLAN:

A. TEACHING STRATEGY:

Group work, individual work, visit, interview.

B.	**DURATION:**	50 minutes + homework.
C.	**EVALUATION:**	Quality of description.
D.	**MATERIALS:**	Reference materials.
E.	**SAFETY MEASURES:**	Not applicable.

SUGGESTED REFERENCES:

LEARNING ACTIVITIES

THE STUDENTS:

7.5.0 Review information documents on careers. (Career Choice Education 111, 211, 311, 451, 551)

7.5.1 List professions associated with the mechanics of motion.

7.5.2 Describe at least one of the professions listed, using reference materials or information from an interview.

7.5.3 Write up reports on their research.

TEACHER'S NOTES:

7. EVALUATION

Evaluation is an integral part of the teaching and learning process. It is first and foremost a way of determining whether students are ready to learn new material, or whether they need remedial activities. Evaluation therefore serves to improve the quality of education and to ensure a favorable learning environment for the students.

Formative and summative evaluation must be consistent with the orientations and the guiding principles of the program. It should verify the degree to which students have assimilated the learning content (skills, knowledge and attitudes) within the framework provided by the terminal objective and defined by the intermediate objectives and the suggested learning activities.

7.1 Evaluation in Accordance with the Principles of the Program

Examinations, be they ministerial or local, are known to condition teaching. For this reason, the evaluation methods should as much as possible take into account the orientations and the related learning content emphasized in the program. Since this program proposes a teaching/learning approach based on the scientific method, the students' approach to solving a problem as well as their solution to the problem should be evaluated. Evaluation should also take into consideration the related content (i.e. skills, knowledge and attitudes).

All the components of this program must be properly implemented if students are to benefit from this new approach to teaching Physics. The methods for evaluating student learning, for both formative and summative evaluation, are essential elements of this new approach.

7.2 Responsibility for Evaluation

Evaluation for the compulsory objectives of Modules 1 and 3 of this program will be carried out by means of a ministry-prepared examination. The Ministère will do its best to ensure that this evaluation is consistent with the orientations of the program. The ministry-prepared examination accounts for 50% of the students' final mark and should consist of two parts: one administered in class, the other in the laboratory.

The partial summative evaluations carried out by either the teacher, the school or the school board during the school year will account for the other 50% of the students' final mark.

Evaluation for all enrichment activities (objectives marked ** and other optional objectives) is the responsibility of the school and/or the school board.

8. IMPLEMENTING THE PROGRAM

The new approach to the teaching of Physics will be successful only if this program is implemented in accordance with all the following elements.

8.1 TARGET POPULATION

In order to take this course, students must have successfully completed Physical Sciences 436.

8.2 STUDENTS' RESPONSIBILITY

Students are ultimately responsible for their own education in that they are the only ones who can decide whether they are going to make the effort to learn. By being active participants in the learning process rather than passive recipients of a flood of information, they will be able to construct the knowledge they will need to meet the challenges of everyday life and to go on to further studies in natural sciences.

Students are expected to do the required classroom work and complete their homework assignments to the best of their abilities. If they have any difficulties, they should approach competent resource persons for assistance.

8.3 PARENTS' RESPONSIBILITY

Parents are expected to take an interest in their children's education and, if necessary, provide them with essential materials that are not supplied by the school, thereby helping to promote the importance of a sound scientific background at a time when science and technology are playing a crucial role in all areas of activity.

8.4 TEACHERS' RESPONSIBILITY

Although our society and the school have tended to take a relatively elitist approach to the teaching of Physics, this subject should be an integral part of all students' general education.

This course is open to all students even if its main goal is to prepare students for Physics or Physics-related studies at the college level.

Science teachers are the primary resource persons and it is their responsibility to guide students through the learning process. They may integrate the suggested learning activities into their courses, or propose others depending on the students' abilities.

Teachers must evaluate student learning and, if necessary, decide upon remedial activities. Stimulating instruction and questions that reflect real life experiences usually motivate students at this level.

8.5 RESPONSIBILITY OF SCHOOL ADMINISTRATORS

School administrators must ensure that this program is implemented in accordance with the orientations it emphasizes. They must also ensure that all lower-level science programs, especially the Physical Sciences programs for Secondary II and Secondary IV, are implemented accordingly. In this way, students will have already been introduced to the approach emphasized in this Physics program.

The school administration is responsible for providing students and teachers with educational materials (e.g. textbooks, laboratory equipment, reference materials, computers, audio-visual materials) that best reflect the orientations of this program and that facilitate students' assimilation of the learning content.

The professional development of teachers is essential to this new approach to teaching Physics. The school administration should provide solid pedagogical support to ensure that current and future teachers upgrade their skills in teaching natural sciences.

8.6 TEACHERS' QUALIFICATIONS

Physics should be taught by teachers who have an excellent background in science and pedagogy. Most teachers start out with this prerequisite, however, many may not have had opportunities to perfect their pedagogical skills since the end of the 1960s when they would have been trained to use the PSSC method developed in the United States.

This Physics program is not based on the PSSC method, nor are its orientations the same. Therefore, in order to be completely familiar with the new approach, teachers need to perfect their pedagogical skills and to practise applying this new method. In-service training for current and future teachers should begin at the same time as the implementation sessions for this program, and be completed in subsequent follow-up sessions.

8.7 SUPPORT STAFF

At least half the objectives of this program must be attained through laboratory work. Laboratory experiments require special and careful preparation and the help of support staff. It is therefore important that teachers be assisted by qualified technicians who can help students use the laboratory materials properly.

8.8 ORGANIZATION OF CLASS TIME

The learning situations that will help students attain the objectives of the program in a manner consistent with its orientations call for regular class periods of sufficient duration for students to complete their work.

8.9 EVALUATION OF LEARNING

Local and ministry-prepared examinations must take into account the learning content and the orientations set out in the program.

8.10 LABORATORY WORK

Since one of the goals of this program is to enable students to become familiar with ways of thinking and work methods necessary to scientific research, students must therefore have access to laboratories where they can carry out the experimental procedures that they have developed, or that were developed beforehand. The school must provide students in this course with the laboratories needed for their experiments.

8.11 EQUIPMENT

Laboratories must be equipped with hot and cold water, electricity and gas and enough quality materials for all students. It is also important that teachers be provided with funds to replace perishable and other materials; these purchases must conform to CSST standards and environmental guidelines.

The Fédération des commissions scolaires catholiques du Québec, with the assistance of the Direction de la formation générale des jeunes, has published a catalogue of materials and products that can be used for this program. The catalogue is available to school boards and private schools.

9. RELATED DOCUMENTS

The following documents, published by the ministère de l'Éducation, are intended to help school personnel implement this program in accordance with the orientations outlined in this program-guide. Other documents may be added to this list at a later date.

La Fédération des commissions scolaires catholiques du Québec. **Catalogue d'équipement, Physique 534**, 1990.

Québec. Ministère de l'Éducation. Direction de la formation générale des jeunes. **Definition du Domaine, Physique 534**. Québec: ministère de l'Éducation, 1991.

Québec. Ministère de l'Éducation. **Guide d'aménagement des classes-laboratoires, Sciences Physiques 4e secondaire**. Québec: ministère de l'Éducation, 1990.

Québec. Ministère de l'Éducation. **Guide to the Handling and Disposal of Hazardous Substances in the Schools**. Code 73-0018A. Québec: ministère de l'Éducation, 1989.

Québec. Ministère de l'Éducation. Direction de la formation générale des jeunes. **Guide for the Implementation of Physics 534**. Québec: ministère de l'Éducation, 1991.

Québec. Ministère de l'Éducation. **Guide spécifique : Cadre de référence à l'intention des auteurs et des évaluateurs du matériel didactique de base conçu en fonction du programme d'études Physique 534**. Québec: ministère de l'Éducation, 1992.

Québec. Ministère de l'Éducation. **Health and Safety in the Teaching of Natural Sciences**. Code 16-3100A. Québec: ministère de l'Éducation, 1990.

Québec. Ministère de l'Éducation. Directions de la formation des jeunes. **Recueils de textes (modules 1, 2, 3)**. Québec: ministère de l'Éducation, 1991.

Québec. Ministère de l'Éducation. **Secondary School Curriculum, Physical Sciences 416-436: The Discovery of Matter and Energy**. Code 16-3175A. Québec: ministère de l'Éducation, 1990.

Québec. Ministère de l'Éducation. **Vidéo - À la découverte de la matière et de l'énergie, Une nouvelle approche**. Québec: ministère de l'Éducation, 1992.

Québec. Ministère de l'Éducation. **Vidéo - Pourquoi?** No. 1200 S092. Québec: ministère de l'Éducation.

Québec. Ministère de l'Éducation. **Vidéo - Santé, sécurité, environment : les substances dangereuses**. No. 3130. Québec: ministère de l'Éducation, 1989.

APPENDIX I

LIST OF SKILLS AND ATTITUDES[1]

1 This is a list of the main skills and attitudes that the student should normally continue to develop if this program is implemented in accordance with the orientations outlined in this document. This classification of skills, attitudes and related indicators should be regarded as a list of suggestions. Teachers may modify it depending on their own preferences or the specific classroom situation.

PART A: SKILLS AND RELATED INDICATORS

Terminal Skills	Intermediate Skills	Indicators
1. Defining a problem (C)	A. Recognizing a problem (C-1)*	• Asking how and why new phenomena occur • Formulating a question or a problem clearly • Identifying all the variables to be measured • Re-examining a question or a problem in the light of new data • Examining the way in which one variable influences another • Identifying the data relevant to the problem
	B. Formulating a hypothesis (Predicting) (C-2)	• Proposing one or more answers to a question • Formulating new hypotheses • Proposing explanations (how, why) for a phenomenon or an observation • Proposing a model • Selecting hypotheses that are consistent with his/her observations • Predicting the influence of one variable on another
	C. Developing an experimental procedure (C-3, C-4)	• Determining the experiments required to test a hypothesis • Determining the variables to be kept constant • Determining the experimental conditions • Identifying sources of danger to human health and safety • Identifying potential dangers for the environment • Selecting appropriate materials and measuring instruments
2. Gathering Information (B, G)	A. Observing (B-1, B-2, G-1, G-2, G-3)	• Using his/her senses (smell, sight, touch...) • Using instruments to supplement his/her observations • Taking precautionary safety measures when observing • Following the established procedure • Working methodically, maintaining order and cleanliness

* The alphanumeric code in parentheses refers to the taxonomy in Appendix II.

Terminal Skills	Intermediate Skills	Indicators
	B. Measuring (B-3, B-4, B-5, G-1, G-2)	• Identifying sources of error • Taking into account the precision of the instrument • Using SI units to measure physical quantities • Reading a measuring instrument correctly • Estimating the absolute error in the measurement of a physical quantity • Interpreting the scale of a measuring instrument • Taking into account significant digits • Monitoring the variables to be kept constant
3. Processing Data (D, E, G)	A. Organizing Data (D-1, D-2, G-2)	• Classifying his/her observations according to one or more specified criteria • Arranging his/her observations, measurements, or data according to specified criteria • Using tables to present numerical data • Using graphs to present numerical data • Proposing a classification system • Constructing a model based on a diagram • Correcting a diagram based on a model
	B. Interpreting Data (D-3, D-4, D-5, E-1, E-2)	• Establishing a relationship between two variables • Interpreting a graph • Representing a phenomenon by means of a mathematical equation • Applying the correct mathematical operators to the data obtained • Selecting observations that are relevant to the research topic • Drawing inferences from the data • Extrapolating beyond actual observations • Interpolating between observations • Taking into account absolute and relative errors when making calculations • Taking into account significant digits when making calculations • Incorporating units of measure into a calculation • Checking whether the result is plausible by analyzing the units used to quantify a physical quantity • Correcting a diagram

Terminal Skill	Intermediate Skills	Indicators
4. Concluding (B, D, E, F)	A. Formulating Generalizations (D-6, B-2, F-1 to F-4)	• Formulating a working definition of an object, a substance or a phenomenon • Describing an object, a substance, or a phenomenon, using models • Identifying an object, a substance, or a phenomenon based on its definition or description • Associating the same explanation with different phenomena • Drawing conclusions • Formulating generalizations based on sufficient data • Formulating a theory • Formulating a law • Identifying everyday phenomena and technological inventions that can be explained through interpretation, a hypothesis, a model, a theory • Identifying phenomena associated with a particular law • Using a model
	B. Constructing a Model (E-1 to E-6)	• Recognizing the need to develop a model • Constructing a physical model on paper or using a three-dimensional building set • Constructing a mathematical model • Writing an equation that represents a transformation • Writing a balanced equation that represents a transformation • Improving a model • Representing an object • Assessing a model • Describing a model
	C. Communicating (F-4)	• Using internationally-accepted terminology and symbols • Presenting work orally and in writing • Communicating using correct language

PART B: ATTITUDES AND RELATED INDICATORS

1. Fascination with science (H-3, H-4, H-6)	• Open (spiritually, intellectually, emotionally, sensorially) to exploring environmental phenomena • Enjoys learning and experimenting • Interested in pursuing a career in science and technology
2. Intellectual curiosity (H-2, H-3, H-4, H-5, I-4)	• Keen on acquiring knowledge • Attracted to the unknown • Confident in his/her ability to find a rational explanation for various phenomena • Fond of research • Interested in scientific activities
3. Willingness to clarify problems (H-3)	• Inclined to define the scope of a question in order to formulate a more clear and precise description of the problem • Inclined to define the scope of a question in order to formulate a description which makes it possible to find a plausible solution based on fact
4. Creative approach (ingenuity) (H-3, F-2)	• Inclined to formulate hypotheses or problem-solving strategies • Capable of drawing a variety of verifiable conclusions based on these hypotheses or problem-solving strategies • Tends to apply his or her knowledge (characteristic of a self-confident, assertive person who accepts ambiguity, who is not afraid to take risks or to rely on intuition)
5. Critical attitude (H-3)	• Inclined to question any assertion or proposition • Inclined to regard an assertion or proposition as a hypothesis • Inclined to organize and conduct experiments to test a hypothesis
6. Objectivity (H-3)	• Inclined to consider only known or verifiable data • Inclined to dismiss subjective data and preconceptions
7. Willingness to interpret information (H-3)	• Inclined to look for a logical line of reasoning, trends, or important characteristics when faced with raw data or seemingly unconnected pieces of information • Inclined to look for the significance of a body of information • Inclined to analyze information

8. Willingness to compare ideas (H-3)	• Inclined to compare his/her work with that of others and with reality in order to assess its merit • Inclined to accept suggestions that could improve the quality of his/her work
9. Willingness to synthesize and apply knowledge (H-3, F-1, F-2, F-3, I-1, I-4)	• Inclined to assess what he/she has learned in order to understand how it relates to other topics • Inclined to apply what he/she has learned to other relevant situations
10. Concern for the use of correct language (F-4)	• Concerned about using the proper word or expression • Always concerned about the meaning of the words or symbols used by other people • Concerned with communicating clearly and concisely
11. Constructivist view of science (H-1, H-2, I-1, I-2, I-3, I-4, I-5)	• Inclined to regard knowledge as the product of intellectual activity, something that must be constructed • Inclined to regard truth as relative and often subject to change • Inclined to regard scientists as fallible human beings who conduct research • Inclined to regard the scientific method as a way of thinking • Inclined to regard scientific knowledge as a system that is constantly evolving • Inclined to regard science as a product of history • Inclined to consider the social dimension of science
12. Sense of responsibility (concern for health and safety, the environment) (G-3, I-4, F-3, H-3, H-4, H-7, H-8)	• Inclined to keep in the best possible physical condition both for his/her own sake and for the general health of society • Inclined to take precautionary measures when doing laboratory or field work • Inclined to act in an environmentally conscious manner • Inclined to recognize the social consequences of scientific and technological development
13. Sense of belonging (H-3, H-7)	• Aware that he/she is a member of a community • Inclined to act for the good of the community
14. Self-confidence (H-3)	• Inclined to express his/her opinions confidently • Inclined to discuss issues confidently • Inclined to defend his/her opinions
15. Conscientiousness (H-3)	• Concerned about producing quality work • Perseverant • Organized • Disciplined

APPENDIX II

TAXONOMY[2]

2 This taxonomy is based on the taxonomy developed by Bloom, Hastings and Madaus (See *Handbook on Formative and Summative Evaluation of Student Learning*. 1971) and on the taxonomy developed by L. E. Klopfer (1971). The authors of this program have made some additions.

A. Knowledge and Comprehension

- A-1 Knowledge of specific facts
- A-2 Knowledge of terminology
- A-3 Knowledge of concepts of science
- A-4 Knowledge of conventions
- A-5 Knowledge of trends and sequences
- A-6 Knowledge of classification, categories and criteria
- A-7 Knowledge of procedures and techniques
- A-8 Knowledge of principles and laws
- A-9 Knowledge of theories or major conceptual schemes
- A-10 Identifying knowledge in a new context
- A-11 Translating knowledge from one symbolic form to another

B. Observing and Measuring

- B-1 Observing objects and phenomena
- B-2 Describing observations
- B-3 Measuring objects and changes
- B-4 Selecting appropriate instruments
- B-5 Estimating measurements and recognizing limits in accuracy

C. Defining a Problem

- C-1 Recognizing a problem
- C-2 Formulating a hypothesis
- C-3 Selecting a test of a hypothesis
- C-4 Designing procedures for performing experiments

D. Interpreting Data and Formulating Generalizations

- D-1 Processing data
- D-2 Presenting data in the form of functional relationships
- D-3 Interpreting data
- D-4 Extrapolating and interpolating
- D-5 Testing a hypothesis
- D-6 Formulating generalizations

E. Constructing a Model

- E-1 Recognizing the need for a theoretical model
- E-2 Formulating a theoretical model
- E-3 Specifying relationships satisfied by a model
- E-4 Deducing new hypotheses
- E-5 Evaluating a model
- E-6 Formulating a revised or refined model

F. Applying Knowledge and Methods

- F-1 Applying knowledge and methods to new problems in the same field of science
- F-2 Applying knowledge and methods to new problems in a different field of science
- F-3 Applying knowledge and methods to problems outside of science and technology
- F-4 Using the written and spoken language specific to a discipline

G. Manual Skills

- G-1 Developing skills in using equipment normally used in laboratory or field work
- G-2 Doing laboratory or field work methodically
- G-3 Doing laboratory or field work carefully and safely

H. Attitudes and Interests

- H-1 Manifesting objective attitudes towards science and scientists
- H-2 Accepting scientific inquiry as a way of thought
- H-3 Adopting "scientific attitudes"
- H-4 Enjoying science learning experiences
- H-5 Developing interests in science and science-related activities
- H-6 Developing an interest in pursuing a career in science or technology
- H-7 Developing a sense of ethics with regard to social issues
- H-8 Showing a concern for the environment

I. Epistemological Orientations

- I-1 Recognizing relationships among various types of statements in science
- I-2 Recognizing the influence and limitations of scientific inquiry
- I-3 Historical perspective: recognizing the background of science
- I-4 Understanding the relationships among science, technology, and society
- I-5 Becoming aware of the social and moral implications of scientific inquiry and its results

APPENDIX III: LIST OF SUGGESTED REFERENCES

AV: Audio-visual Media Materials

B: Books

CS: Computer Software

M: Magazines and Periodicals

AV: AUDIO VISUAL MEDIA MATERIALS

AV-1 **Bell and Fiber Optics**, Bell Canada, 1982 (5 min 16 mm)

AV-2 **Fiber Optics**, Bell Canada, (10 min VHS)

AV-3 **Vectors**, MEQ, Radio-Québec, Québec School Television (600 Fullum, 5th Floor, Montréal, H2K 3L6, Tel. (514) 521-2424, ext. 4219), (60 min VHS)

AV-4 **Frames of Reference 1: Carts**, #307C-0267-724 NFB (Filmloop, PHYSICS II Series)[1]

AV-5 **Frames of Reference 2: Airplane**, #307C-0267-726 NFB (Filmloop, PHYSICS II Series)

AV-6 **Frames of Reference 4: Snowmobile**, #307C-0267-727 NFB (Filmloop, PHYSICS II Series)

AV-7 **Hurdle Race 2**, #307C-0267-729 NFB (Filmloop, PHYSICS II Series)

AV-8 **One-Dimensional Collisions 2**, #307C-0267-739 NFB (Filmloop, PHYSICS II Series)

AV-9 **Inelastic Collisions in One Dimension**, #307-0267-740 NFB (Filmloop, PHYSICS II Series)

AV-10 **Collisions in Two Dimensions 1**, #307C-0267-741 NFB (Filmloop, PHYSICS II Series)

AV-11 **Collisions in Two Dimensions 2**, #307C-0267-742 NFB (Filmloop, PHYSICS II Series)

AV-12 **Inelastic Collisions in Two Dimensions**, #307C-0267-743 NFB (Filmloop, PHYSICS II Series)

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[1] The codes for these filmloops are provided for identification purposes only as they are no longer available through the NFB. To obtain this material, contact the audio-visual library of your school or school board.

AV-13 **Scattering a Group of Objects by a Collision**, #307C-0267-744 NFB (Filmloop, PHYSICS II Series)

AV-14 **Scattering a Group of Objects by an Explosion**, #307-0267-745 NFB (Filmloop, PHYSICS II Series)

AV-15 **Measuring the Velocity of a Bullet 1**, #307C-0267-746 NFB (Filmloop, PHYSICS II Series)

AV-16 **Measuring the Velocity of a Bullet 2**, #307C-0267-747 NFB (Filmloop, PHYSICS II Series)

AV-17 **The Recoil of a Cannon**, #307C-0267-748 NFB (Filmloop, PHYSICS II Series)

AV-18 **The Dynamics of a Billiard Ball**, #307C-0267-750 NFB (Filmloop, PHYSICS II Series)

AV-19 **Kinetic Energy**, #307C-0267-753 NFB (Filmloop, PHYSICS II Series)

AV-20 **Conservation of Energy: Pole Vault**, #307C-0267-754 NFB (Filmloop, PHYSICS II Series)

AV-21 **Conservation of Energy: an Airplane Taking Off**, #307C-0267-755 NFB (Filmloop, PHYSICS II Series)

AV-22 **Free Fall**, #307C-0267-757 NFB (Filmloop, PHYSICS II Series)

AV-23 **Stationary Waves**, #307C-0267-758 NFB (Filmloop, PHYSICS II Series)

AV-24 **Stationary Sound Waves**, #307C-0267-759 NFB (Filmloop, PHYSICS II Series)

AV-25 **Stationary Electromagnetic Waves**, #307C-0267-760 NFB (Filmloop, PHYSICS II Series)

AV-26 **Stationary Waves: Rubber Tubes**, #307C-0267-761 NFB (Filmloop, PHYSICS II Series)

AV-27 **Stationary Waves: Metal Rods**, #307C-0267-762 NFB (Filmloop, PHYSICS II Series)

AV-28 **Stationary Waves: Metal Sheets**, #307C-0267-764 NFB (Filmloop, PHYSICS II Series)

AV-29 **Collision with an Unknown Object**, #307C-0267-768 NFB (Filmloop, PHYSICS II Series)

AV-30 **Types of Movements**, #0265754 NFB (Filmloop, PHYSICS II Series)

AV-31 **Hurdle Race 1**, #307C-0267-728 NFB (Filmloop, PHYSICS II Series)

AV-32 **Central Forces**, #307C-0267-735 NFB (Filmloop, PHYSICS II Series)

AV-33 **Frames of Reference** (PSSC Film) Ward's Natural Science Ltd., (397 Vansickle Road, St Catherines, Ontario, L2S 3T5), (28 min VHS)

AV-34 **Vector Addition: Velocity of a Boat**, #307C-0267-721 NFB (Filmloop, PHYSICS II Series)

AV-35 **Free Fall**, #307C-0164-085 NFB (Filmloop, PHYSICS II Series)

AV-36 **Instantaneous Velocity 1**, #307C-0267-751 NFB (Filmloop, PHYSICS II Series)

AV-37 "Air Track Collision", **Demonstration of Physics by Dennis Harp**, Volume 2: Vikas Production Inc., P.O. Box 6088, Bozeman, MT 59771, (VHS or Beta, $89.95 US)

AV-38 **Free Fall and Projectile Motion**, (PSSC film), Ward's Natural Science Ltd., Op. Cit., (27 min VHS)

AV-39 **Eureka** TVO (3 video cassettes, 30 minutes each, 30 parts, 4 min 55 seconds each), MEQ Radio-Québec, Québec School Television, Op. Cit.

AV-40 "Inertia", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-41 "Mass", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-42 "Speed", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-43 "Acceleration 1", **Eureka Series**, Unit 1, TV Ontario 4 min 55 seconds

AV-44 "Acceleration 2", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-45 "Gravity", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-46 "Weight and Mass", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-47 "Work", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-48 "Kinetic Energy", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-49 "Potential Energy", **Eureka Series**, Unit 1, TV Ontario, 4 min 55 seconds

AV-50 "Radiation Spectrum", **Eureka Series**, Unit 3, TV Ontario, 4 min 55 seconds

AV-51 "The Inclined Plane", **Eureka Series**, Unit 2, TV Ontario, 4 min 55 seconds

AV-52 "Mechanical Advantage and Friction", **Eureka Series**, Unit 2, TV Ontario, 4 min 55 seconds

AV-53 "The Pulley", **Eureka Series**, Unit 2, TV Ontario, 4 min 55 seconds

AV-54 **Falling Bodies and Projectile Motion**, Visual Education Centre, (75 Horner Avenue, Unit One, Etobicoke, Ontario, M8Z 4X5) (19 min VHS)

AV-55 **Friction: A First Film**, International Tele-Film, (47 Densley Ave., Toronto, Ontario, M6M 5A8) (7-minute Film)

AV-56 **Learning About Light**, Marlin Motion Pictures Ltd., (211 Watline Ave., Mississauga,

Ontario, L4Z 1P3) (15 min VHS)

AV-57 **Light and Color**, Marlin Motion Pictures Ltd., Op. Cit., (10 min 16 mm)

AV-58 **Light and Images**, Coronet Film & Video, (3771 Victoria Park Ave., Scarborough, Ontario, M1W 2P9) (10 min VHS)

AV-59 **Light and the Electromagnetic Spectrum**, Coronet Film & Video, Op. Cit., (13 min VHS)

AV-60 **Light, Color and the Visible Spectrum**, Coronet Film & Video, Op. Cit., (14 min VHS)

AV-61 **Collisions, Classroom Video**, (Unit C, 9005 Centaurus Circle, Burnaby, B.C., V3J 7N4), (18 min VHS)

AV-62 **Periodic Motion**, (PSSC Film), Ward's Natural Science Ltd., Op. Cit. (33 min 16 mm)

AV-63 **Falling Motion**, Films for the Humanities and Science Inc., (PO Box 1051, Fort Erie, Ontario, L2A 5N8) (8 min VHS)

AV-64 **Simple Machines: Working Together**, Coronet Film & Video, Op. Cit., (13 min 16 mm)

AV-65 **Stationary Transverse Waves**, (PSSC Films), CRM/McGraw-Hill Films, (330 Progress Ave., Scarborough, Ontario, M1P 9Z9) (9 min 16 mm)

AV-66 **Vibrations**, Marlin Motion Pictures Ltd., Op. Cit. (14 min 16 mm)

AV-67 **Wave Motion: Introductory Concepts in Physics**, Films for the Humanities and Science Inc., Op. Cit., (3 Films 35 minutes total, Color)

AV-68 **Dynamics: Introductory Concepts in Physics**, Films for the Humanities and Science Inc., Op. Cit., (11 Films 96 minutes total, Color)

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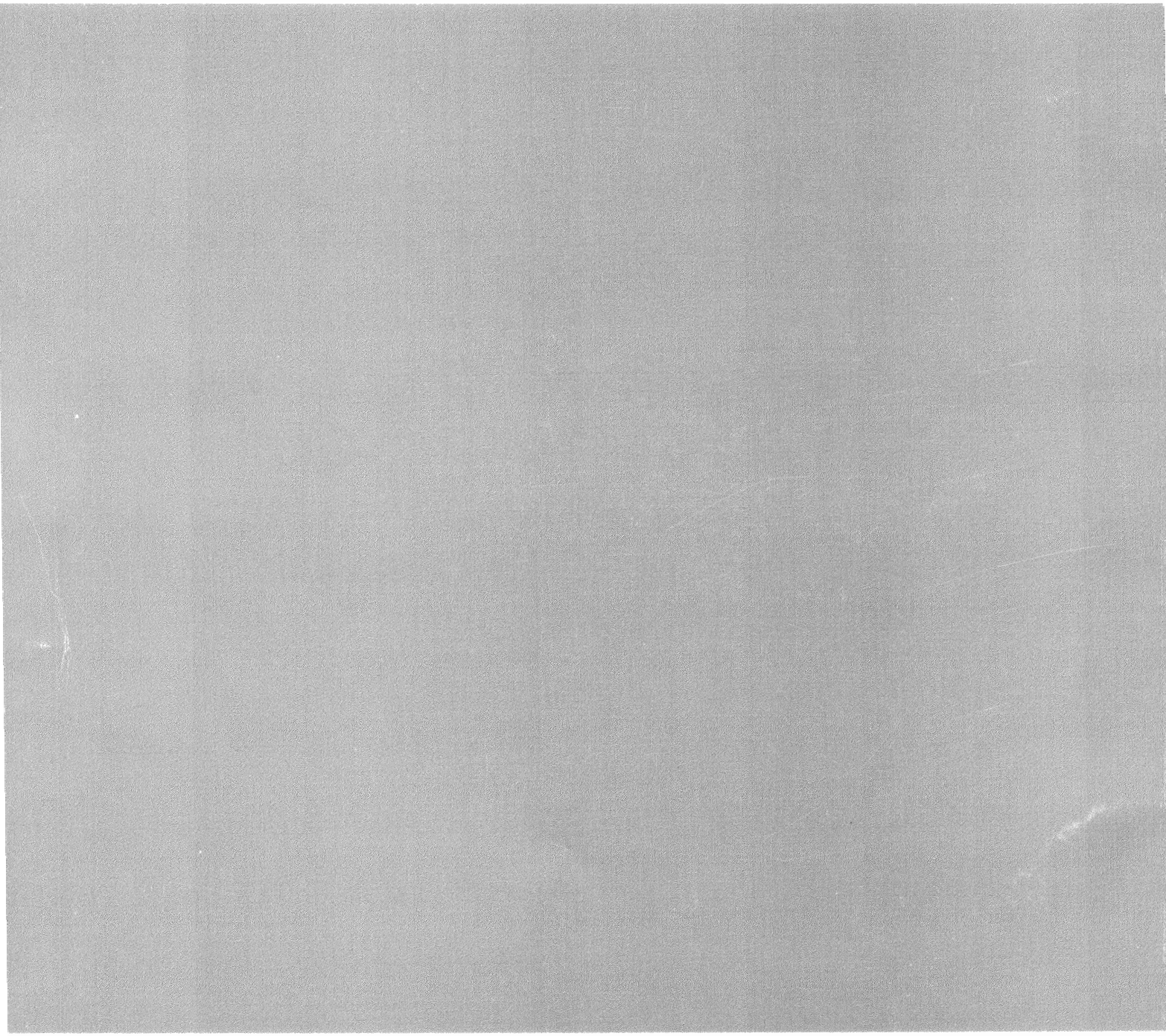

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