Science Education Key Learning Area

Physics Curriculum Guide (Secondary 4-5)

Prepared by
The Curriculum Development Council

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(From March 1997 to August 1999)

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PREAMBLE

This Curriculum Guide is one of the series prepared by the Hong Kong Curriculum Development Council for use in secondary schools.

The Curriculum Development Council is an advisory body giving recommendations to the Hong Kong Special Administrative Region Government on all matters relating to curriculum development for the school system from kindergarten to sixth form. Its membership includes heads of schools, practising teachers, parents, employers, academics from tertiary institutions, professionals from related fields or related bodies, representatives from the Hong Kong Examinations Authority and the Vocational Training Council, as well as officers from the Education Department.

This Curriculum Guide is recommended by the Education Department for use in secondary schools. The curriculum developed for the senior secondary levels normally leads to appropriate examinations provided by the Hong Kong Examinations Authority.

The Curriculum Development Council will review the curriculum from time to time in the light of classroom experiences. All comments and suggestions on the Curriculum Guide may be sent to:

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I. AIMS AND OBJECTIVES

Aims

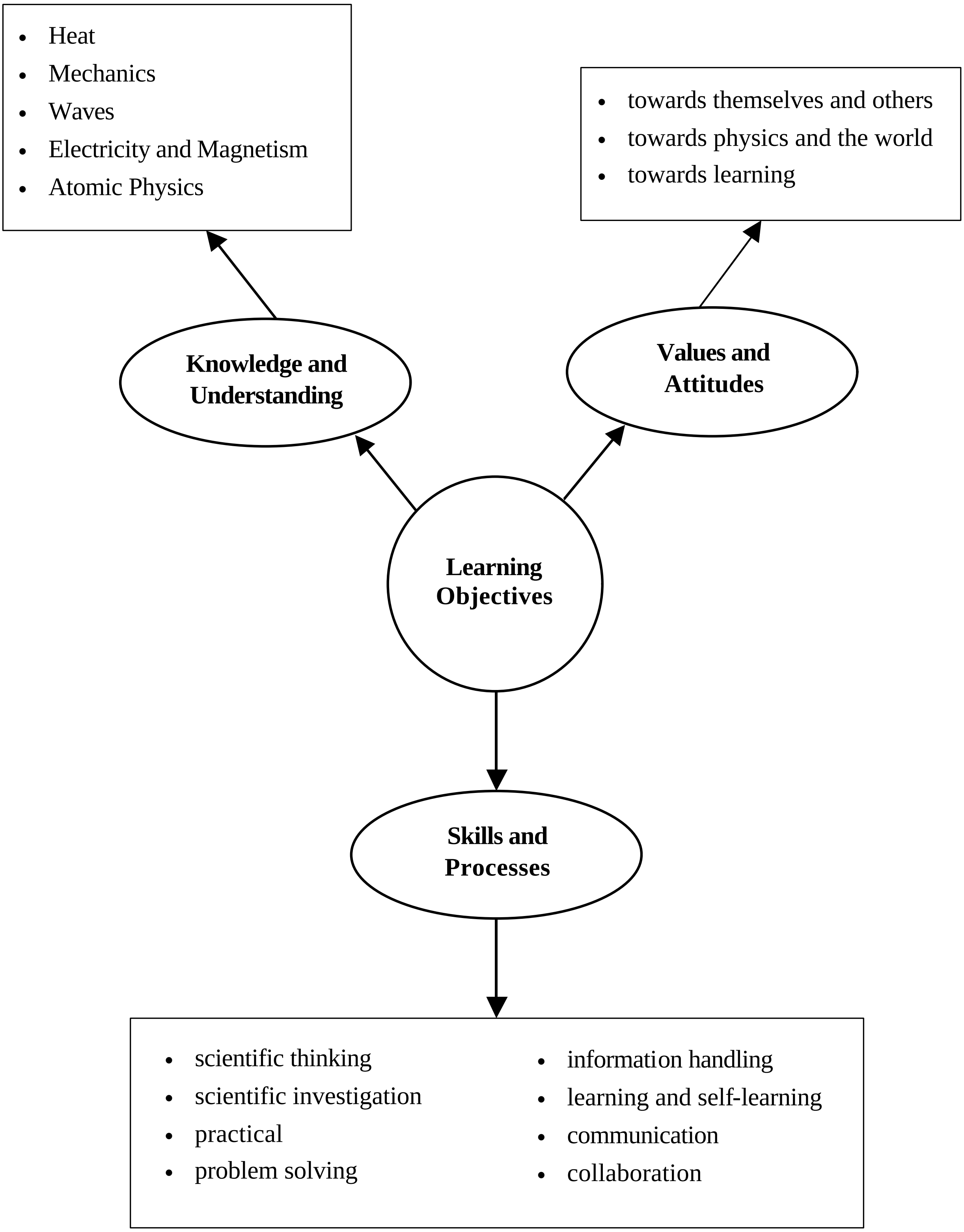
The paramount aim of the science education in Hong Kong is to provide learning experiences for students to engage in scientific processes for understanding and application of scientific concepts and principles, and recognise the impact and cultural significance of scientific and technological developments. These learning experiences will form a solid foundation on which students communicate ideas and make informed judgements, develop further in the field of physics, science and technology, and become life-long learners in these fields of study.

The broad aims of this physics curriculum are to enable students to

- develop interest, motivation and a sense of achievement in their study of physics;
- develop an appreciation of the nature of physics, the historical and current development in physics;
- understand the fundamental principles and concepts of physics and its methodology;
- develop an awareness of the relevance of physics to their daily life;
- acquire the basic scientific knowledge and concepts for living in and contributing to a scientific and technological world;
- recognise the usefulness and limitations of science and the interactions between science, technology and society;
- develop an attitude of responsible citizenship, including respect for the environment and commitment to the wise use of resources;
- develop the ability to describe and explain concepts, principles, systems, processes and applications related to physics using appropriate terminologies;
- develop skills relevant to the study of physics such as scientific investigation, problem solving, experimental technique, collaboration, communication, mathematical analysis, information searching and processing, analytical and critical thinking and self-learning;
- develop positive values and attitudes towards physics, themselves and others through the study of physics;
- carry out further studies and embark upon careers in fields related to physics; and
- recognise the role of the applications of physics in the fields of science, engineering and technology.

Objectives

The following is a schematic inter-relationship diagram on the Objectives of the physics curriculum:



The general objectives listed below are to be developed through a course of study of physics at S4-5 level as a whole. They are categorized into three domains: Knowledge and Understanding, Skills and Processes, and Values and Attitudes. Being at a general level, they are applicable to all the sections of the physics curriculum. Objectives specifically related to individual sections will be highlighted in the chapter on **CURRICULUM FRAMEWORK**.

A. Knowledge and Understanding

Students should be able to

1. recall terms, facts, concepts, principles, theories and models in physics;
2. show understanding of the subject using physics vocabulary and terminology;
3. show knowledge of techniques and skills specific to the study of physics;
4. apply knowledge and principles of physics to familiar and unfamiliar situations; and
5. show understanding of the technological applications of physics and of the social implications of these.

B. Skills and Processes

1. scientific thinking

Students should be able to

1.1 identify attributes of objects or natural phenomena;
1.2 identify patterns and changes in the natural world and predict trends from them;
1.3 examine evidence and apply logical reasoning to draw valid conclusions;
1.4 present concepts of physics in mathematical terms whenever appropriate;
1.5 appreciate the fundamental role of models in exploring observed natural phenomena;
1.6 appreciate that models are modified as new or conflicting evidences are found;
1.7 examine theories and concepts through logical reasoning and experimentation;
1.8 recognise preconceptions or misconceptions with aid of experimental evidence; and
1.9 group and organise knowledge and concepts and apply to new situations.

2. scientific investigation

Students should be able to

2.1 ask relevant questions in scientific investigations;
2.2 propose hypotheses for scientific phenomena and devise methods to test them;
2.3 identify dependent and independent variables in investigations;
2.4 devise plans and procedures to carry out investigations;
2.5 select appropriate methods and apparatus to carry out investigations;
2.6 observe and record experimental observations accurately and honestly;
2.7 organise and analyse data, and infer from observations and experimental results;
2.8 use graphical techniques appropriately to display experimental results and to convey concepts of physics;
2.9 produce reports on investigations, draw conclusions and make further predictions;
2.10 evaluate the quality and reliability of experimental results and identify factors affecting their quality and reliability; and
2.11 propose plans for further investigations if appropriate.

3. practical

Students should be able to

3.1 follow procedures to carry out laboratory experiments;
3.2 handle apparatus properly and safely;
3.3 measure to the accuracy allowed by the instruments; and
3.4 recognise the limitations of instruments used.

4. problem solving

Students should be able to

4.1 clarify and analyse problems related to physics;
4.2 apply knowledge and principles of physics to solve problems;
4.3 suggest creative ideas or solutions to problems;
4.4 propose solution plans and evaluate the feasibility of these plans; and
4.5 devise appropriate strategies to deal with issues that may arise.

5. information handling

Students should be able to

5.1 search, retrieve, reorganise, analyse and interpret scientific information from libraries, the media, the Internet and multi-media software packages;
5.2 use information technology to manage and present information, and to develop habits of self-learning;
5.3 be wary of the accuracy and credibility of information from secondary sources; and
5.4 distinguish among fact, opinion and value judgement in processing scientific information.

6. learning and self-learning

Students should be able to

6.1 develop their study skills to improve the effectiveness and efficiency of learning;
6.2 engage in simple self-learning activities in the study of physics; and
6.3 develop basic learning habits, abilities and attitudes that are essential to the foundation of life-long learning.

7. communication

Students should be able to

7.1 read and understand articles involving physics terminology, concepts and principles;
7.2 use appropriate terminology to communicate information related to physics in oral, written or other suitable forms; and
7.3 organise, present and communicate physics ideas in a vivid and logical manner.

8. collaboration

Students should be able to

8.1 participate actively, share ideas and offer suggestions in group discussions;

8.2 liaise, negotiate and compromise with others in group work;
8.3 identify collective goals, define and agree on roles and responsibilities of members in science projects requiring team work;
8.4 act responsibly to accomplish allocated tasks;
8.5 be open and responsive to ideas and constructive criticisms from team members;
8.6 build on the different strengths of members to maximize the potential of the team;
8.7 demonstrate willingness to offer help to less able team members and to seek help from more able members; and
8.8 implement strategies to work effectively as a member of the project team.

C. Values and Attitudes

1. towards themselves and others

Students should

1.1 develop and possess positive values and attitudes such as curiosity, honesty, respect for evidence, perseverance and tolerance of uncertainty through the study of physics;
1.2 develop a habit of self-reflection and the ability to think critically;
1.3 be willing to communicate and comment on issues related to physics and science;
1.4 develop open-mindedness and be able to show tolerance and respect towards the opinions and decisions of others even in disagreement; and
1.5 be aware of the importance of safety for themselves and others and be committed to safe practices in their daily life.

2. towards physics and the world we are living in

Students should

2.1 appreciate the achievements made in physics and recognise the limitations;
2.2 accept the provisional status of the knowledge and theory of physics;
2.3 apply the knowledge and understanding of physics rationally in making informed decision or judgement on issues in their daily life; and
2.4 be aware of the social, economic, environmental and technological implications of the achievement of physics.

3. towards learning as a life-long process

Students should

3.1 recognise the consequences of the evolutionary nature of scientific knowledge and understand that the constant up-dating of knowledge is important in the world of science and technology;

3.2 be exposed to and develop an interest in the new developments of physics, science and technology; and

3.3 recognise the importance of life-long learning in our rapidly changing knowledge-based society.

II. CURRICULUM FRAMEWORK

A. Organisation

The physics curriculum builds on the CDC Syllabus for Science (Secondary 1-3) published in 1998, in which some basic physics concepts on Forces and Motion, Energy, Electricity and Light have been introduced. The fundamental principles of these topics are further developed in this curriculum. Other topics are also covered to provide a coherent and comprehensive view of the world of physics.

1. Domains

The physics curriculum consists of three domains: Knowledge and Understanding, Skills and Processes, and Values and Attitudes. Objectives for these domains, which are described in detail in the chapter on **AIMS AND OBJECTIVES**, contribute to the whole personal development of a student. Students are to acquire and integrate the concepts and skills from various parts of the curriculum in order to develop a coherent and holistic view of physics. Ideas as well as materials from social issues and everyday experiences of students should be incorporated to fulfil the objectives.

2. Core and Extension

The content of the curriculum consists of two components, Core and Extension. The Core is the basic component of senior secondary level physics for all students whereas the Extension component is generally more demanding and more suitable for students aiming to pursue further study in the subject. For some students, it will be more beneficial, less stressful and more effective to just concentrate on the Core component so that more time is available to master the basic concepts and principles; for others, the challenges provided by the Extension component may provide a higher degree of achievement. A good school-based physics course should have an in-built flexibility to cater for the interest and abilities of students so that a balance between the quantity and quality of learning may be achieved.

3. Experiments and Investigations

Scientific investigations and experiments are essential to the study of physics. Through hands-on practical activities, students are expected to acquire science practical skills identified in the chapter on **AIMS AND OBJECTIVES** and detailed in the individual sections. By participating in the process of scientific enquiry, students will bring the scientific method to the processes of problem solving, decision-making and evaluation of evidence. A good school-based physics course should be organised to provide a significant amount of experimental and investigational work so that students have opportunities to develop their practical skills as well as higher order thinking skills. Teachers may design or adopt experiments and investigations to bring out the teaching points in an effective manner. In particular, experiments and investigations closely related to relevant contexts will enhance learning effectiveness.

All practical work should be performed by students under proper teacher supervision to ensure that safety measures are observed. Teachers are advised to try out new or unfamiliar experiments beforehand so that any potentially dangerous situations can be uncovered before students are involved.

B. Time Allocation

A time allocation of four 40-minute periods each week for Secondary 4 and 5 would be adequate to cover this curriculum. The time allocation below is compiled for the entire physics curriculum consisting of both the Core and the Extension components. It gives an estimation of the number of periods required to cover the individual sections. Project work, presentation, discussion and article reading are important elements of this curriculum. Whereas some of these activities may be conducted by students themselves outside normal school hours, about 30 periods could be set aside for these activities within normal curriculum time. Teachers should integrate these elements into the curriculum appropriately.

		No. of Periods
Project work, presentation, discussion, article reading		30
Section 1	**Heat**	18
	1.1 Temperature, Heat and Internal Energy	
	1.2 Transfer Processes	
	1.3 Change of State	
Section 2	**Mechanics**	45
	2.1 Position and Movement	
	2.2 Force and Motion	
	2.3 Work, Energy and Power	
	2.4 Momentum	
Section 3	**Waves**	42
	3.1 Nature and Properties of Waves	
	3.2 Light	
	3.3 Sound	
Section 4	**Electricity and Magnetism**	42
	4.1 Electrostatics	
	4.2 Circuits and Domestic Electricity	
	4.3 Electromagnetism	
Section 5	**Atomic Physics**	15
	5.1 Radiation and Radioactivity	
	5.2 Atomic Model	
	5.3 Nuclear Energy	
	Total:	**192**
		(Equivalent to 128 hours)

C. Content

The content of the curriculum is organised into five sections. However, the concepts and principles of physics, being inter-related, cannot be confined by any artificial boundaries of the sections. In the knowledge content of each section, sub-topics that are assigned to the Extension component are underlined. The order of presentation of the sections, or the materials within each section, should not be regarded as the recommended teaching sequence. Teachers should adopt sequences that best suit their chosen teaching approaches. For instance, some parts of a certain section may be covered in advance if they fit in naturally within a chosen context.

There are five major parts in each of the following sections: ***Overview***, ***Knowledge and Understanding***, ***Skills and Processes***, ***Values and attitudes*** and ***Science, Technology and Society (STS) connections***.

(a) ***Overview*** **–** outlines the main theme of the section. The major concepts and important physics principles to be acquired will be highlighted. The foci of each section will be briefly described. The interconnections between sub-topics will also be outlined.

(b) ***Knowledge and Understanding*** **–** lists out what are the major topics required in the knowledge content domain of the syllabus. It provides a broad framework upon which learning and teaching activities can be developed.

(c) ***Skills and Processes*** **–** gives suggestions to some of the different skills that are expected to be acquired in the section. Some important processes associated with the section are also briefly described. Since most of the generic skills can be acquired through any of the sections, there is no attempt to give directive recommendation on the activities that should be performed. Students need to acquire a much broader variety of skills than what are mentioned in the sections. Teachers should use their professional judgement to arrange practical and learning activities to develop the skills of students as listed in the chapter on **AIMS AND OBJECTIVES**. It should be done through an appropriate integration with the knowledge content, taking into consideration students' abilities and interest as well as school contexts.

(d) ***Values and Attitudes*** **–** suggests some desirable values and attitudes related to the section. Students are expected to develop such intrinsically worthwhile values and positive attitudes in the course of a study in physics. Through discussions and debates, students are encouraged to form their value judgement and develop good habits for the benefit of themselves and society.

(e) ***STS connections*** – suggests some issue-based learning activities related to the topics in the section. Students should be encouraged to develop an appreciation and apprehension of issues which reflect the interconnections of science, technology and society. Through discussion, debate, information search and project work, students can develop their skills of communication, information handling, critical thinking and making informed judgement. Teachers are free to select other current, relevant topics and issues of high profile in the public agenda as themes of meaningful learning activities.

Section 1 Heat

Overview

This section examines the concept of internal energy and energy transfer processes related to heat. Particular attention is placed on the distinction and relationship between temperature, internal energy and energy transfer. Students are also encouraged to adopt microscopic interpretations of various important concepts on the topic of heat.

Calculations involving specific heat capacities will be used to complement the theoretical aspects of heat and energy transfer. The practical importance of the high specific heat capacity of water can be illustrated with examples close to the experiences of students. A study of conduction, convection and radiation provides a basis for analysing the containment of internal energy and transfer of energy related to heat. The physics involving the change of states is examined and numerical problems involving the specific latent heat are used to consolidate the theoretical aspects of energy conversion.

Knowledge and Understanding

Students should learn:

1.1 Temperature, heat and internal energy

temperature and thermometers	• temperature as the degree of hotness of an object • <u>interpretation of temperature as a quantity associated with average kinetic energy due to the random motion of the molecules in a system</u> • use of temperature-dependent properties to measure temperature • degree Celsius as a unit of temperature • fixed points on the Celsius scale

Students should learn:

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heat and internal energy

- heat as the energy transferred resulting from the temperature difference between two objects
- internal energy as the energy stored in a system
- interpretation of internal energy as the sum of the kinetic energy of random motion and the potential energy of the molecules in a system

heat capacity and specific heat capacity

- definitions of heat capacity and specific heat capacity
- application of the formula $Q = mc(T_2\text{-}T_1)$ to solve problems
- practical importance of the high specific heat capacity of water

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1.2 Transfer processes

conduction, convection and radiation

- conduction, convection and radiation as means of energy transfer
- interpretation, in terms of molecular motion, of energy transfer by conduction in solids and by convection in fluids
- emission of infra-red radiation by hot objects
- factors affecting the emission and absorption of radiation

1.3 Change of state

melting and freezing, boiling and condensing

- melting point and boiling point

latent heat

- latent heat as the energy transferred during a change of state at constant temperature
- interpretation of latent heat in terms of the change of potential energy of the molecules during a change of state

Students should learn:

	• definitions of specific latent heat of fusion and specific latent heat of vaporization • application of the formula $Q = mL$ to solve problems
evaporation	• occurrence of evaporation below boiling point • cooling effect of evaporation • factors affecting rate of evaporation • <u>interpretation of evaporation in terms of molecular motion</u>

Skills and Processes

Students should develop experimental skills in temperature and energy measurements. The precautions essential for accurate measurements in heat experiments should be understood in terms of the concepts learnt in this section. Students should also be encouraged to suggest their own methods for improving the accuracy of these experiments, and arrangements for performing these investigations should be made if they are feasible. In some of the experiments, a prior understanding of electrical energy may be required to provide a firm understanding of the energy transfer processes involved.

Values and Attitudes

Students should develop intrinsically worthwhile values and attitudes in the course of a study in physics; some particular examples are:

- to be aware of the proper use of heat-related domestic appliances as it helps to reduce the cost of electricity and contributes to the worthwhile cause of saving energy
- to be aware of the large amount of energy associated with heat transfer and to develop good habits when using air-conditioning in summer and heating in winter
- to develop an interest in alternative environment friendly energy resources such as solar cookers and geothermal energy
- to be aware of the importance of home safety in relation to the use of radiation heaters and

to be committed to safe practices in their daily life

STS connections

Students are encouraged to develop an appreciation and apprehension of issues which reflect the interconnections of science, technology and society; some examples of such issues and topics related to this section are:

- the importance of greenhouses in agriculture and the environmental issue of the 'Greenhouse Effect'
- debates on the gradual rise in global temperature due to human activities, the associated potential global hazard due to the melting of the polar ice caps, and the effects on the world's agricultural production
- projects, such as the 'Design of Solar Cookers', can be used to develop the investigation skill as well as to foster the concept of using alternative environment friendly energy resources

(Note: The underlined text represents the extension part of the curriculum.)

Section 2 Mechanics

Overview

In this section, the fundamentals of mechanics are introduced, and the foundation for describing motion with physics terminologies is laid. Various types of graphical representations of motion are studied. Students learn how to analyse different forms of motion and solve simple problems relating to uniformly accelerated motion. They also learn the rules governing the vertical motion of objects on Earth.

The concept of inertia and its relation to Newton's first law of motion is covered. Simple addition and resolution of forces are used to illustrate the vector properties of forces, and free-body diagrams are used to work out the net force acting on a body. Newton's second law of motion, which relates the acceleration of an object to the net force, is examined. The concepts of mass, weight and gravitational force are introduced. Newton's third law of motion is related to the nature of forces.

The concepts of mechanical work done and energy transfer are examined and used in the derivation of kinetic energy and gravitational potential energy. The treatment of energy conversion is used to illustrate the law of conservation of energy, and the concept of power is also studied. Students learn how to compute quantities such as momentum and energy in examples on collisions. The relationship between the change in momentum of a body, impact time and impact force is emphasised.

Knowledge and Understanding

Students should learn:

2.1 Position and movement

position, distance and displacement	• description of the change of position of objects in terms of distance and displacement • displacement-time graphs for moving objects

Students should learn:

scalars and vectors	• distinction between scalar and vector quantities • use of scalars and vectors in different contexts
speed and velocity	• average speed and average velocity • <u>distinction between instantaneous and average speed /velocity</u> • description of motion of objects in terms of speed and velocity
uniform motion	• definition of uniform motion • application of the formula $s = vt$ for uniform motion • velocity-time graphs of objects in uniform motion
acceleration	• velocity-time graphs of objects in uniformly accelerated motion in one direction <u>and with a change in direction</u> (including the interpretation of slope and area) • definition of acceleration as the rate of change of velocity • formula $a = \frac{v-u}{t}$ for uniformly accelerated motion along a straight line • acceleration-time graphs of objects in uniformly accelerated motion in one direction <u>and with a change in direction</u>
equations of uniformly accelerated motion	• equations of uniformly accelerated motion $v = u + at$ $s = \frac{1}{2}(u+v)t$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ • problem solving of uniformly accelerated motion for journeys in one direction <u>and with a change in direction</u>

Students should learn:

vertical motion under gravity	• free-falling objects have the same acceleration (*g*) • description and graphical representation of vertical motions of free-falling objects in one direction and with a change in direction • problem solving of vertical motions in one direction and with a change in direction using the equations of uniformly accelerated motion • qualitative treatment of the effect of air resistance on the motion of objects falling under gravity

2.2 Force and motion

Newton's first law of motion	• meaning of inertia and mass • Newton's first law of motion • application of the first law to explain situations in which objects are at rest or in uniform motion • friction as a force opposing relative motion between 2 surfaces
addition of forces	• addition of forces graphically and algebraically in one dimension • addition of forces graphically and algebraically in two dimensions
resolution of forces	• resolution of a force graphically and algebraically in two mutually perpendicular directions
Newton's second law of motion	• effect of a net force on the speed and direction of motion of an object • Newton's second law of motion and the equation $F = ma$ • definition of a unit of force, newton

Students should learn:

	• use of free-body diagrams to show the forces acting on objects and to identify the net force in a system consisting of one or two objects • application to solve problems involving rectilinear motion in one direction <u>and with a change in direction</u>
Newton's third law of motion	• forces act in pairs • Newton's third law of motion • identification of the action and reaction pair of forces
mass and weight	• distinction between mass and weight • relationship between mass and weight $W = mg$

2.3 Work, energy and power

mechanical work	• mechanical work done as a measure of energy transfer • definition of mechanical work done $W = Fs$ • definition of a unit of energy, joule, with reference to the equation $W = Fs$ • application of the formula $W = Fs$ to solve problems
gravitational potential energy (P.E.)	• gravitational potential energy of an object due to its position under the action of gravity • derivation of the formula $E_P = mgh$ • application of the formula $E_P = mgh$ to solve problems
kinetic energy (K.E.)	• kinetic energy of a moving object • derivation of the formula $E_K = \frac{1}{2}mv^2$ • application of the formula $E_K = \frac{1}{2}mv^2$ to solve problems
law of conservation of energy	• interpretation of the law of conservation of energy

Students should learn:

	• inter-conversion of P.E. and K.E., taking into account of energy loss • application of the law of the conservation of energy to solve problems
power	• definition of power in terms of the rate of energy transfer • definition of a unit of power, watt • application of the formula $P = \frac{W}{t}$ to solve problems

2.4 <u>**Momentum**</u>

<u>linear momentum</u>	• <u>definition of momentum as a quantity of motion of an object *p* = *mv*</u>
<u>change in momentum and net force</u>	• <u>change in momentum resulted when a net force acts on an object for a period of time</u> • <u>interpretation of force as the rate of change of momentum (Newton's second law of motion)</u>
<u>law of conservation of momentum</u>	• <u>interpretation of the law of conservation of momentum</u>
<u>elastic and inelastic collisions</u>	• <u>distinction between elastic and inelastic collisions</u> • <u>application of the law of conservation of momentum to solve problems involving collisions in one dimension</u> • <u>energy changes in collisions</u>

Skills and Processes

Students should develop experimental skills in time measurements and in the recordings of positions, velocities and accelerations of objects using various types of measuring instruments such as stop watches, data-logging sensors etc. Skills in the measurements of masses, weights and forces are also required. Data handling skills such as converting displacement and time data into information on velocity or acceleration are important. Students may be encouraged to carry out project-type investigations in the motion of vehicles. There is much emphasis on the importance of graphical representations of physical phenomena in this section. Students should learn how to plot graphs with suitable choices of scales, display experimental results in graphical forms and interpret, analyse and draw conclusions from graphical information. In particular, they should learn to interpret the physical significances of slopes, intercepts and areas in certain graphs.

Values and Attitudes

Students should develop intrinsically worthwhile values and attitudes in the course of a study in physics; some particular examples are:

- to be aware of the importance of car safety and to be committed to safe practices in their daily life
- to be aware of the potential danger of falling objects from high-rises and to adopt a cautious attitude in matters concerning public safety
- to be aware of the environmental implications of the different modes of transport and to make an effort in reducing energy consumptions in daily life
- to appreciate the efforts made by scientists to find more alternative environment friendly energy resources
- to appreciate that the advancement of important scientific theories (such as Newton's laws of motion) can ultimately make huge impacts on technology and society
- to appreciate the roles of science and technology in the exploration of outer-space and to appreciate the efforts of mankind in the quest for the understanding of nature

STS connections

Students are encouraged to develop an appreciation and apprehension of issues which reflect the interconnections of science, technology and society; some examples of such issues and topics related to this section are:

- the effects of energy use on the environment
- the reduction of pollutants and energy consumption by restricting the use of private cars in order to protect the environment
- the penalizing of drivers and passengers who do not wear seatbelts and the raising of public awareness of car safety with scientific rationales
- how the danger of speeding, and its relation to the chances of serious injury or death in car accidents, can be related to the concepts of momentum and energy
- modern transport: the dilemma in choosing between speed and safety; the dilemma in choosing between convenience and protection of the environment
- the ethical issue of dropping objects from high-rises and its potential danger based on the principles of physics

(Note: The underlined text represents the extension part of the curriculum.)

Section 3 Waves

Overview

This section examines the basic nature and properties of waves. Light and sound, in particular, are studied in detail. The concept of waves being a means of transmitting energy without transferring matter is emphasised. The foundation for describing wave motion with physics terminologies is laid. Students learn the graphical representations of travelling waves. The basic properties and characteristics displayed by waves are examined; reflection, refraction, diffraction and interference are studied using simple wavefront diagrams.

Students acquire a specific knowledge on light in two important aspects. The characteristics of light as a part of the electromagnetic spectrum are studied. Besides, the linear propagation of light in the absence of significant diffraction and interference effects is used to explain image formation in the domain of geometric optics. The formation of real and virtual images using mirrors and lenses are studied using the construction rules for light rays.

Sound as an example of longitudinal waves is examined. Its general properties are compared with those of light waves. Students also learn about ultrasound. The general descriptions of musical notes are related to the terminologies of waves. The effects of noise pollution and the importance of acoustic protection are also studied.

Knowledge and Understanding

Students should learn:

3.1 Nature and properties of waves

nature of waves	• oscillations in a wave motion • waves transmitting energy without transferring matter

Students should learn:

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wave motion and propagation

- distinction between transverse and longitudinal travelling waves
- description of wave motions in terms of: waveform, crest, trough, compression, rarefaction, wavefront, displacement, amplitude, period (T), frequency (f), wavelength (λ), wave speed (v)
- displacement-time and displacement-distance graphs for travelling waves
- application of $f = 1/T$ and $v = f\lambda$ to solve problems

reflection, refraction and diffraction

- reflection of waves at a plane barrier/reflector
- refraction of waves across a straight boundary
- refraction of waves due to a change in speed
- diffraction of waves through a narrow gap and around a corner
- relationship between the degree of diffraction and size of the gap compared to the wavelength
- illustration of reflection, refraction and diffraction of waves using wavefront diagrams

interference of waves

- interference of waves as a property of waves
- occurrence of constructive and destructive interferences
- interference of waves from two coherent sources
- conditions for constructive and destructive interference in terms of path difference
- illustration of interference of waves using wavefront diagrams

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Students should learn:

3.2 Light

wave nature of light	• light as an example of transverse waves • light as a part of the electromagnetic spectrum • range of the wavelength for visible light • relative positions of visible light and the other parts of the electromagnetic spectrum • speed of light and electromagnetic waves in vacuum
reflection of light	• laws of reflection • graphical constructions of image formation by a plane mirror
refraction of light	• laws of refraction • path of a ray being refracted at a boundary • definition of refractive index of a medium $n = \sin i / \sin r$ • application of Snell's law to solve problems involving refraction at a boundary between vacuum(or air) and another medium
total internal reflection	• conditions for total internal reflection • problem solving involving total internal reflection and critical angle at a boundary between vacuum(or air) and another medium
formation of images by lenses	• graphical constructions of image formation by converging and diverging lenses • distinction between real and virtual images
evidence for the wave nature of light	• diffraction and interference as evidences for the wave nature of light

Students should learn:

3.3 Sound

wave nature of sound	• sound as an example of longitudinal waves • requirement of a medium for the transmission of sound waves • comparison of the general properties of sound waves and light waves
audible sound	• range of frequency for audible sound waves
ultrasound	• frequencies of ultrasound
musical notes	• comparison of musical notes using the terms pitch, loudness and quality • association of the frequency and amplitude with the pitch and loudness of a note respectively
noise	• representation of the sound intensity level using the unit decibel • effects of noise pollution and the importance of acoustic protection

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Skills and Processes

Students should develop experimental skills in the study of vibration and waves through various physical models. They need to develop the skills for interpreting indirect measurements and demonstrations of wave motion through the displays on a CRO or computer. They should appreciate that many scientific evidences are obtained through indirect measurements coupled with logical deduction. They should also be aware that various theoretical models are used in the study of physics; for example, the ray model is used in geometric optics for image formation and the wave model of light is used to explain such phenomena as diffraction and interference. Through the study of the physics of musical notes, students should develop an understanding that most everyday experiences are explainable with the aid of scientific concepts.

Values and Attitudes

Students should develop intrinsically worthwhile values and attitudes in the course of a study in physics; some particular examples are:

- to appreciate the need to use more alternative environment friendly energy resources such as solar cells and tidal-wave energy
- to be aware that science has its limitations and cannot always provide clear-cut solutions; the advancement of science also requires perseverance, openness and scepticism, as demonstrated in the different interpretations on the nature of light in the history of physics over the past centuries
- to appreciate that the advancement of important scientific theories (such as those related to the study of light) are the fruits of generations of scientists who devoted their lives to scientific investigations by applying their intelligence, knowledge and skills
- to be aware of the potential health hazard of a prolonged exposure to extremely loud noisy environment and to make an effort to reduce noise-related disturbances to neighbours
- to be aware of the importance of the proper use of microwave ovens and to be committed to safe practices in their daily life

STS connections

Students are encouraged to develop an appreciation and apprehension of issues which reflect the interconnections of science, technology and society; some examples of such issues and topics related to this section are:

- controversial issues about the effects of microwave radiation on the health of the general public through the use of mobile phones
- the biological effects on the human body of an increased ultra-violet radiation from the Sun as a result of the formation of the depletion of ozone layer of the atmosphere caused by artificial pollutants
- the problem of noise pollution in the local context
- the impact on the society as a result of the scientific discovery of electromagnetic waves and the technological advancements in the area of telecommunication

- how major breakthroughs in scientific and technological development that eventually affect society are associated with new understanding of fundamental physics as traced out by the study of light in the history of science
- how technological advancements can provide impetus for scientific investigations as demonstrated in the invention and development of the microscope, telescope and X-ray diffraction etc.; these scientific investigations in turn shed light on our own origin and the position of mankind in the universe

(Note: The underlined text represents the extension part of the curriculum.)

Section 4 Electricity and Magnetism

Overview

This section examines the basic principles of electricity and magnetism. The abstract concept of an electric field is introduced through its relationship with an electrostatic force. The inter-relationships between voltage, current, resistance, charge, energy and power are examined and a foundation for basic circuitry is laid. The practical use of electricity in households is studied with particular emphasis on the safety aspects.

The concept of magnetic field is applied to a study of electromagnetism. The magnetic effect of an electric current and some simple magnetic field patterns are studied. Students also learn the factors that affect the strength of an electromagnet. The magnetic force produced when a current-carrying conductor is placed in a magnetic field is studied and an application of the principle is used to understand the operation of a simple d.c. motor.

The general principles of electromagnetic induction are introduced, and the operation of simple d.c. and a.c. generators are studied. Students learn how a.c. voltages can be stepped up or down using transformers. The system by which electrical energy is transmitted over great distances to our homes is studied.

Knowledge and Understanding

Students should learn:

4.1 Electrostatics

electric charges	• experimental evidences for two kinds of charges in nature • attraction and repulsion between charges • representation of a quantity of charge using the unit coulomb • <u>charging in terms of electron transfer</u>

Students should learn:

	electric field	• existence of an electric field in the region around a charged body • representation of an electric field using field lines

4.2 Circuits and domestic electricity

	electric current	• an electric current as a flow of electric charges • definition of a unit of current, ampere, as one coulomb per second • convention for the direction of an electric current
	electrical energy and voltage	• energy transformations in electric circuits • definition of voltage as the energy transferred per unit charge passed • volt as a unit of voltage
	resistance and Ohm's law	• Ohm's law • definition of resistance $R = V/I$ • ohm as a unit of resistance • application of the formula $V = IR$ to solve problems • factors affecting the resistance of a wire
	series and parallel circuits	• comparison of series and parallel circuits in terms of the voltages across the components of each circuit and the currents through them • relationships $R = R_1 + R_2 + \ldots$ for resistors connected in series $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$ for resistors connected in parallel

Students should learn:

simple circuits	• determination of *I, V* and *R* in simple circuits • <u>effects of resistance of ammeters, voltmeters and cells in simple circuits</u>
electrical power	• heating effect when a current passes through a conductor • application of the formula $P = VI$ to solve problems
domestic electricity	• power rating of electrical appliances • kilowatt-hour (kW h) as a unit of electrical energy • calculation of the costs of running various electrical appliances • household wiring and the safety aspects of domestic electricity • operating current for an electrical appliance and the selection of power cable and fuse

4.3 Electromagnetism

magnetic force and magnetic field	• attraction and repulsion between magnetic poles • existence of a magnetic field in the region around a magnet • representation of a magnetic field using field lines • behaviour of a compass in a magnetic field
magnetic effect of an electric current	• existence of a magnetic field due to moving charges and electric currents • magnetic field patterns associated with currents through a long straight wire, a circular coil and a long solenoid • factors affecting the strength of an electromagnet

Students should learn:

current-carrying conductor in a magnetic field	• existence of a force on a current-carrying conductor in a magnetic field and determination of its direction • factors affecting the force on a current-carrying conductor in a magnetic field • turning effect on a current-carrying coil in a magnetic field • operating principle of a simple d.c. motor
electromagnetic induction	• induction of voltage when a conductor cuts magnetic field lines and when the magnetic field through a coil changes • application of Lenz's law to identify the direction of an induced current in a closed circuit • operating principles of simple d.c. and a.c. generators
transformer	• operating principle of a simple transformer • relationship between the voltage ratio and turns ratio $\frac{V_p}{V_s}=\frac{N_p}{N_s}$ and its application to solve problems • efficiency of a transformer • methods for improving the efficiency of a transformer
high voltage transmission of electrical energy	• advantage of the transmission of electrical energy with a.c. at high voltages • various stages of stepping up and down of the voltage in a grid system for power transmission

Skills and Processes

Students should develop experimental skills in connecting up circuits. They are required to perform electrical measurements using various types of equipment such as ammeters, voltmeters, multi-meters, joulemeter, CRO and data-logging probes. Students should acquire the skills in setting up experiments to study, demonstrate and explore the concepts of physics such as electric fields, magnetic fields and electromagnetic induction. Students can gain practical experiences related to design and engineering in building physical models such as electric motors and generators. It should, however, be noted that all experiments involving the mains power supply and EHT supply must be carefully planned to avoid the possibility of an electric shock, and that handling apparatus properly and safely is a very basic practical skill of great importance.

Values and Attitudes

Students should develop intrinsically worthwhile values and attitudes in the course of a study in physics; some particular examples are:

- to appreciate that the application of scientific knowledge can produce useful practical products and transform the daily-life of human beings as demonstrated in the numerous inventions related to electricity
- to be aware of the importance of technological utilities such as electricity to the modern society and the effects on modern life if these utilities are not available for whatever reason
- to be aware of the need to save electrical energy for reasons of economy as well as environmental protection
- to be committed to the wise use of natural resources and to develop a sense of shared responsibility for a sustainable development of mankind
- to be aware of the danger of electric shocks and the fire risk associated with an improper use of electricity and develop good habits in using domestic electricity

STS connections

Students are encouraged to develop an appreciation and apprehension of issues which reflect the interconnections of science, technology and society; some examples of such issues and topics related to this section are:

- the effects on health as a result of living near high power transmission cables
- the potential hazard of the mains supply versus the conveniences of ‘plug-in’ energy and automation it offers to society
- the environmental implications and recent developments of the electric car as an alternative to the traditional fossil-fuel car; the role of government on such issues

- the views of some environmentalists on the necessity to return to a more primitive or natural life-style with minimum reliance on technology

(Note: The underlined text represents the extension part of the curriculum.)

Section 5 Atomic Physics

Overview

In this section, atomic processes are examined. A simple model of the atom is used to explain some of the processes, and the origin of radioactivity, together with the nature and properties of radiation, are studied. Students learn simple methods for the detection of radiation as well as the major sources of background radiation in our natural environment. Simple numerical problems involving half-lives are performed and used to understand the long-term effects of some radioactive sources. The potential hazard of ionizing radiation is studied scientifically and in a balanced way by bringing in the concept of dosage.

In the atomic model, the basic structure of a nuclide is represented using a symbolic notation. Students learn the concepts of isotopes. They are also introduced to fission and fusion, nature' s most powerful energy sources.

Knowledge and Understanding

Students should learn:

5.1 Radiation and Radioactivity

X-ray	• X-ray as an ionizing electromagnetic radiation of short wavelength with high penetrating power • emission of X-rays when fast electrons hit a heavy metal target
α, β and γ radiation	• origin and nature of the α, β and γ radiation • comparisons of the α, β and γ radiation in terms of penetrating power, range, ionizing power, deflections in electric and magnetic fields, and cloud chamber tracks

Students should learn:

radioactive decay	• occurrence of radioactive decay in unstable nuclides • random nature of radioactive decay • proportional relationship between the activity of a sample and the number of undecayed nuclei • definition of half-life • determination of the half-life of a radioisotope from its decay graph or from numerical data • problem solving involving the half-life
detection of radiation	• detection of radiation using a photographic film and G-M counter • measurement of radiation in terms of the count rate using a G-M counter
radiation safety	• major sources of the background radiation • representation of a radiation dose using the unit sievert • potential hazard of ionizing radiation and the ways to minimize the radiation dose absorbed • safety precautions in handling radioactive sources

5.2 Atomic model

atomic structure	• structure of a typical atom • definitions of atomic number and mass number • use of symbolic notations to represent nuclides
isotopes and radioactive transmutation	• definition of isotope • existence of radioactive isotopes in some elements • representation of radioactive transmutations in α, β and γ decays in terms of equations

Students should learn:

5.3 Nuclear energy

nuclear fission	• release of energy in a nuclear fission • nuclear chain reaction
nuclear fusion	• release of energy in a nuclear fusion • nuclear fusion as the source of solar energy

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Skills and Processes

Students must be properly warned about the potential danger of radioactive sources. The regulations regarding the use of radioactivity for school experiments must be strictly observed. Although students are not allowed to handle sealed sources, they can acquire experimental skills by participating in the use of the Geiger-Muller counter in an investigation of the background radiation. Fire alarms making use of weak sources may also be used in student experiments under teacher supervision. However, proper procedures should be adopted and precautions should be taken to avoid accidental detachment of the source from the device. Analytic skills are often required to draw meaningful conclusions from the results of radioactive experiments that inevitably involve the background radiation.

Values and Attitudes

Students should develop intrinsically worthwhile values and attitudes in the course of a study in physics; some particular examples are:

- to be aware of the usefulness of models and theories in physics as shown in the atomic model and appreciate the wonders of nature
- to be aware of the need to use natural resources judiciously to ensure the quality of life for future generations
- to be aware of the benefits and disadvantages of nuclear energy resources compared to fossil fuels

- to be aware of the views of society on the use of radiation: the useful applications of radiation in research, medicine, agriculture and industry are set against its potential hazards
- to be aware of different points of views in society on controversial issues and appreciate the need to respect others' points of view even in disagreement; and to adopt a scientific attitude when facing controversial issues such as debates on the use of nuclear energy

STS connections

Students are encouraged to develop an appreciation and apprehension of issues which reflect the interconnections of science, technology and society; some examples of such issues and topics related to this section are:

- the use of nuclear power; the complex nature of the effects caused by developments in science and technology on our society
- the moral issue of using various mass destruction weapons in wars
- the political issue of nuclear deterrents
- the roles and responsibilities of scientists and the related ethics in releasing the power of nature as demonstrated in the developments of nuclear power
- stocking and testing of nuclear weapons
- the use of fission reactors and related problems such as radioactive wastes and leakage of radiation

III. LEARNING AND TEACHING

Learning effectiveness depends on the motivation of students and their prior knowledge, the learning contexts, teaching methods and strategies, and assessment practices. To learn effectively, students should take an active role in science learning processes. Appropriate teaching strategies and assessment practices should be employed with this view in mind.

A. Teacher's role

Teachers should be well acquainted with the aims and objectives of the curriculum and arrange meaningful learning activities for their fulfilment. They should timely and appropriately employ different learning and teaching approaches, and play the roles of a resource person, facilitator and assessor. Teachers are encouraged to use different strategies such as discussion, practical work and project learning to facilitate students' learning. The learning process can be enhanced by stimulating students to think, encouraging students to explore and inquire, and giving appropriate guidance and encouragement to students according to individual needs. The followings are some suggestions made in accordance with these observations.

Designing teaching sequence

The topics in the curriculum are listed in a possible teaching sequence. However, different teaching sequences can be adopted to enhance learning. Teachers are encouraged to design teaching sequences for their particular groups of students.

Catering for students' abilities

In deciding teaching strategies, students' abilities should be given due consideration, and it is unrealistic to expect every student to achieve the same level of attainment. In this curriculum, the core and extension parts are suggested for different ability groups. Teachers should have the flexibility to devise teaching schemes with appropriate breadth and depth according to the abilities of their own students and to make learning challenging but not too demanding. This can pave the way to enjoyable learning experiences.

To cater for students with a strong interest or outstanding abilities in physics, teachers can set more challenging learning objectives on top of those described in this document. Teachers should exercise their professional judgement to implement this curriculum so that students would not be deprived of opportunities to develop their full potential.

Moreover, time allocations for the sections are suggested in the chapter on **CURRICULUM FRAMEWORK**. Rough-and-ready as they are, these estimates could nonetheless provide useful guidance to teachers as to the depth of treatment required and the weighting to be placed on each section.

Teaching with a Contextual approach

Learning is most effective if it is built upon the existing background knowledge of students. Learning through a real-life context accessible to students will increase their interest and enhance the learning of physics. The context-based learning highlights the relevance of physics to students' daily life and can be employed to enhance their awareness of the inter-relationships between science, technology and society. When the original concepts have been learned with effectiveness, confidence and interest, the transfer of concepts, knowledge and skills to other contexts can then be made. Teachers are strongly encouraged to adopt a contextual approach in an implementation of the curriculum.

Designing learning activities

Teachers should motivate students through a variety of ways such as letting them know the goals and expectations of learning, building on their successful experiences, meeting their interest and considering their emotional reactions. Learning activities are designed according to these considerations. Some examples of these activities are given below.

Article reading
Students should be given opportunities to read independently science articles of appropriate breadth and depth. The abilities to read, interpret, analyse and communicate new scientific concepts and ideas can then be developed. Meaningful discussions on good science articles among students and with teachers may also be used to strengthen general communication skills. The abilities of self-learning developed this way will be invaluable in preparing students to become active life-long learners.

A variety of articles, which may be used to emphasise the interconnections between science, technology and society, will serve the purposes of broadening and enriching the curriculum, bringing into which current developments and relevant issues. Teachers may select suitable articles for their own students according to their interest and abilities, and students are encouraged to search for such articles from newspapers, science magazines and the Internet. The main purpose of this part of the curriculum is to encourage reading. The factual knowledge acquired is of relatively minor importance; whereas rote memorization of the contents is undesirable and should be discouraged.

Discussions and debates

Discussions and debates in the classroom promote students' understanding, and help them develop higher order thinking skills as well as an active learning attitude. One of the most effective ways to motivate students is to make discussions or debates relevant to their everyday life. Presenting arguments allows students to extract useful information from a variety of sources, to organise and present ideas in a clear and logical form, and to make valid judgements based on scientific evidence. Teachers can start a discussion with issues related to science, technology and society, and invite students to freely express their opinions in the discussion, at the end of which students can present their ideas to the whole class and receive comments from their teacher and classmates.

Teachers must avoid discouraging discussions in the classroom by insisting too much and too soon on an impersonal and formal scientific language. It is vital to accept relevant discussions in students' own language during the early stages of concept learning, and to move towards precision and accuracy of scientific usage in a progressive manner.

Practical work

Physics is a practical subject and thus practical work is essential for students to gain a personal experience of science through doing and finding out. In the curriculum, designing and performing experiments are given due emphases.

Teachers should avoid giving manuals or worksheets for experiments with ready-made data tables and detailed procedures, for this kind of instructional materials provide fewer opportunities for students to learn and appreciate the process of science. With an inquiry-based approach, students are required to design all or part of the experimental procedures, and to decide what data to record and how to analyse and interpret the data. Students will show more curiosity and sense of responsibility for their own experiments leading to significant gains in their basic scientific skills.

Moreover, experiments are better designed to "find out" rather than to "verify". Teachers should avoid giving away the answers before the practical work, and students should try to draw their own conclusions from the experimental results. The learning of scientific principles will then be consolidated.

Experiments

Include

- designing and planning
- prediction of results
- manipulation of apparatus
- collection of data
- consideration of safety

→

Conclusions and interpretations

Include

- analysis of experimental results
- evaluation of predictions
- explanation for deviations from predictions

→

Scientific Principles

Include

- generalisation of patterns and rules from conclusions and interpretations

Project Learning

Learning through project work, a powerful strategy to promote self-directed, self-regulated and self-reflecting learning, enables students to connect knowledge, skills, and values and attitudes, and to accumulate knowledge through a variety of learning experiences. It also serves to develop a variety of skills such as scientific problem solving, critical thinking and communication. Project work can be carried out individually or in small groups, and students will plan, read and make decision over a period of time. Project work carried out in small groups can enhance the development of collaboration skills, while that involving experimental investigations can help develop practical skills as well.

Searching and presenting information

Searching for information is an important skill to be developed in the information era. Students can gather information from various sources such as books, magazines, scientific publications, newspapers, CD-ROMs and the Internet. Searching for information can cater for knowledge acquisition and informed judgements by students, but the activity should not just be limited to the collecting of information. Its selecting and categorizing and the presentation of findings should also be included.

Using Information technology (IT) for interactive learning

IT is a valuable tool for interactive learning, which complements the strategies of learning and teaching inside and outside the classroom. Teachers should select and use IT-based resources as appropriate to facilitate students' learning. However, an improper use of IT might distract student attention, have little or no educational value and may sometimes cause annoyance.

There are numerous and growing opportunities to use IT in a science education. IT can help search, store, retrieve and present scientific information. Interactive computer-aided learning programmes can enhance the active participation of students in a learning process. A computer-based laboratory interface allows students to collect and analyse data, vary parameters, and find out mathematical relationships between variables. Simulation and modelling tools can be employed to effect exploratory and interactive learning processes.

Providing life-wide learning opportunities

A diversity of learning and teaching resources should be used appropriately to enhance the effectiveness of learning. Life-wide learning opportunities should be provided to widen the exposure of students to the scientific world. Examples of learning programmes serving this purpose include popular science lectures, debates and forums, field studies, museum visits, invention activities, science competitions, science projects and science exhibitions. Students with good abilities or a strong interest in science may need more challenging learning opportunities. These programmes can stretch students' science capabilities and allow them to develop their full potential.

B. Student's role

As active learners, students should initiate, organise, make decisions and take responsibility for their own learning, and participate in the learning activities with their hands-on and minds-on. To foster the ownership of learning, students need to be guided to and engaged in setting own goals, develop own criteria of assessment and evaluate own progress. The feeling of ownership generates enthusiasm.

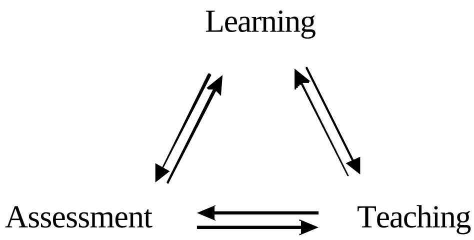
The following are activities that can enhance students' learning.

- Collecting specimens
- Performing practical work
- Proposing questions
- Designing experiments
- Completing project work
- Participating in discussions
- Taking part in role play
- Participating in debates
- Conducting surveys
- Brainstorming
- Demonstrating in front of a class
- Presenting ideas
- Sharing experiences
- Writing reports
- Reading books, newspapers, magazines, periodicals, etc.
- Searching for information from CD-ROMs, the Internet, etc.
- Following self-instructional materials
- Constructing concept maps and composing notes
- Evaluating their own performance
- Attending seminars and exhibitions

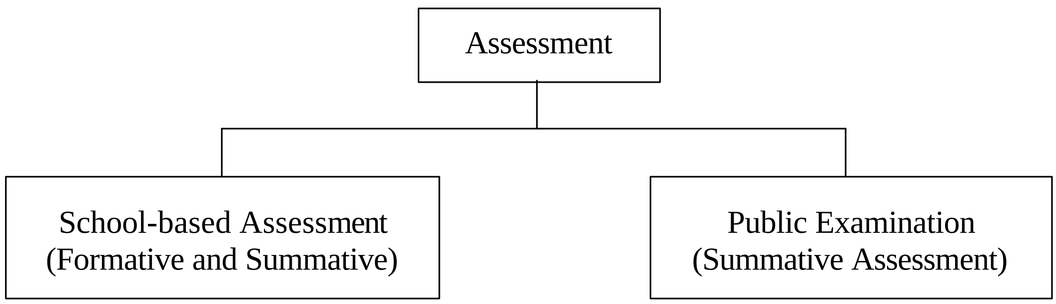
Students should learn to transfer skills learnt from one context to another. The transferability of the process of investigation and the acquisition of new knowledge will help students continue to learn. When students start to believe in themselves, confidence will grow. This in turn breeds positive feelings and motivation resulting in an effective learning. The skills and habits developed in an active learning are essential for students to become life-long learners.

IV. ASSESSMENT

Assessment is the practice of collecting evidence of progress in students' learning. It is an integral part of the learning and teaching cycle. Assessment provides information for both teachers and students on the processes of learning and teaching.



In order to bring about improvements in learning and teaching, it is essential that any assessment should be aligned to the processes of learning and teaching. Apart from the better known summative assessment which would normally be identified with tests, end-of-term examinations and public examinations, a formative assessment need to be introduced to serve as a diagnostic tool to help improving students' learning. Further, school-based assessments, both formative and summative, should be given due consideration.



The formative assessment should be carried out on a continuous basis and through different ways such as oral questioning, observation of students' performance, assignments, project work, practical tests and written tests. It should be integrated with learning and teaching throughout the course with the purpose of promoting the quality and effectiveness of learning and teaching. It should provide feedback to teachers who could then make decision about what should be done next to enhance students' learning; sometimes it may lead to the employment of a more appropriate teaching method. It should also provide feedback to students so that they understand how to improve their learning.

Assessment Domains

Assessment provides information on students' achievement in relation to the set objectives. It is important that not only the objectives in the domain of knowledge and understanding are assessed, but those related to skills and processes, being essential to the study of physics, should also be assessed throughout the course.

Higher order skills such as problem solving and decision making can be tested by using questions based on information which is unfamiliar to students who are required to use the principles and concepts learnt and apply them in a logical manner to a novel situation. In tests on abilities in analysis and evaluation with the use of open-ended questions, students are expected to consider as many relevant aspects as possible before forming their judgements. In tests on communication skills, students are expected to give essay-type answers, presenting arguments clearly and logically.

For objectives related to values and attitudes, a certain degree of flexibility in assessment may be employed. Observations, interviews, essay writing and students' self-assessment are some of the possible assessment strategies.

Assessment Strategies

In the learning and teaching of physics, a number of assessment strategies can be used. Teachers should have plans on how to assess students' achievements and should let students know how they will be assessed.

Paper and pencil tests

Paper and pencil tests have been widely employed as the major method of assessment in schools. However, the prolonged reliance on this type of assessment would have a narrowing effect on learning, and probably teaching too. Teachers should refrain from the temptation of teaching knowledge and understanding that can only be assessed by paper and pencil tests. Teachers should also avoid testing only basic information recall and should try to construct test items that assess the understanding of concepts, problem solving abilities and higher order thinking skills. Incorporation of open-ended questions in tests and examinations could also help evaluating students' creativity and critical thinking skills.

Written assignments

The written assignment is widely used in learning and teaching processes. It is a good assessment tool since it continuously reflects students' efforts, achievements, strengths and weaknesses. Comments on students' written work, with concrete suggestions on how to improve it, give a valuable feedback to students. Teachers are encouraged to make use of students' written assignments as a formative assessment tool to show students' progress in learning. As a means of evaluation, assignments can also reflect the effectiveness of teaching, provide a feedback upon which teachers can set further targets for students, and make reasonable adjustments in their teaching.

Oral questioning

Oral questioning can provide teachers promptly with specific information on how the students think in certain situations. Students' responses often provide clues to their strengths, weaknesses, misunderstandings, levels of understanding, interest, attitudes and abilities. Teachers are encouraged to use questions targeting a range of abilities, from those require only recall of facts to those demand higher order thinking. In addition, a balance of both open-ended and closed-ended questions should be maintained, and questions or problems, based on information which is unfamiliar to students, could be set.

Observation

While students are working in groups or individually, teachers could take the opportunity to observe and note the different aspects of students' learning. When students are engaged in learning activities, teachers could observe the approaches students take to solve problems and their attitudes to work, such as perseverance, independence, cooperation, and willingness to address difficulties. In practical sessions, teachers could look for the choices students make in regard to the equipment they use, the safety measures they adopt, the activities they prefer, whom they work with, and the interaction with others. Teachers should keep brief records and use such information for making further judgements about students' learning.

Practical assessment

Whether the assessment of practical skills by written tests and examinations is desirable or appropriate deserves further deliberation. It is generally agreed that more suitable strategies for assessing these skills are direct observations or practical tests, i.e. assessing in an authentic environment where learning and assessments are integrated, and a feedback can be given to students immediately. Students' laboratory or investigation reports can also be assessed so that more information about students' performance can be obtained.

Project work

Project work, a powerful learning and teaching as well as assessment strategy, allows students not only to exercise` their practical skills and apply what they have learnt, but also to employ various other skills in addition to thinking processes such as identifying problems, formulating hypotheses, designing and implementing strategies and evaluation. Teachers can make use of a combination of assessment strategies to collect evidence of student learning in the knowledge and skill domains, and gauge their creativity, communication skills, collaboration skills and problem solving abilities. Teachers can also make use of appropriate criteria to assess students' values and attitudes demonstrated in the process of doing a project.

The assessment strategies suggested above are by no means exhaustive. A combination of assessment strategies can provide a more vivid picture of students' achievements, and teachers should explore various assessment strategies for their own students.

Public Examination

The Hong Kong Examinations Authority (HKEA) organises the Hong Kong Certificate of Education Examination (HKCEE) to assess students' attainment, and publishes annually a physics examination syllabus which serves to provide information to teachers and students so that they have a clear understanding of the examination requirements. It should be read along with this document.

Given the mode of assessment adopted in the HKCEE, it is neither possible nor desirable to translate all the learning objectives into assessment objectives. Teachers should note the assessment objectives of the HKEA syllabus are based on the learning objectives suggested in this Curriculum. However, teachers should not ignore the learning objectives not included in the assessment objectives.

Appendix: Reference Books

Title	Author	Publisher	Year of Publication
100 Years of Radium Marie Curie and the History of Radiochemistry	Amersham, N.	Association for Science Education	1999
Active Physics – Communication	Eisenkraft, A.	It' s About Time, Inc	2000
Active Physics – Home	Eisenkraft, A.	It' s About Time, Inc	2000
Active Physics – Medicine	Eisenkraft, A.	It' s About Time, Inc	2000
Active Physics – Predictions	Eisenkraft, A.	It' s About Time, Inc	2000
Active Physics – Sports	Eisenkraft, A.	It' s About Time, Inc	2000
Active Physics - Transportation	Eisenkraft, A.	It' s About Time, Inc	2000
AKSIS Investigations – Targeted Learning	AKSIS Project	Association for Science Education	2001
Complete Physics	Pople, S.	Oxford University Press	1999
Conceptual Physics	Hewitt, P.	Addison-Wesley	1999
Coordinated Science - Physics	Jones, M., Jones, G. & Marchington, P.	Cambridge University Press	1997
Core Physics	Milner, B.	Cambridge University Press	1999
Core Science Homework	Milner, B. & Martin, J.	Cambridge University Press	1999
Data logging in practice	Frost, R.	IT in Science	1999
Developing Understanding in Scientific Enquiry	Goldsworthy, A. & Wastson, R.	Association for Science Education	2000
Extension Physics	Milner, B.	Cambridge University Press	1998
GCSE Physics	Duncan, T.	John Murray	1995
GCSE Science for OCR A: Physics Double Award	McDuel, B., Mitchell, S., & Sherry, C.	Heinemann	2001

Title	**Author**	**Publisher**	**Year of Publication**
GCSE Science for OCR A: Physics Separate Award	McDuel, B., Mitchel, S., & Sherry, C.	Heinemann	2001
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