Science Education
Key Learning Area

Physics
Curriculum and Assessment Guide
(Secondary 4 - 6)

Jointly prepared by the Curriculum Development Council and
The Hong Kong Examinations and Assessment Authority

Recommended for use in schools by the Education Bureau
HKSARG
2007 (with updates in November 2015)

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Preamble

The Education and Manpower Bureau (EMB, now renamed Education Bureau (EDB)) stated in its report[1] in 2005 that the implementation of a three-year senior secondary academic structure would commence at Secondary 4 in September 2009. The senior secondary academic structure is supported by a flexible, coherent and diversified senior secondary curriculum aimed at catering for students' varied interests, needs and abilities. This Curriculum and Assessment (C&A) Guide is one of the series of documents prepared for the senior secondary curriculum. It is based on the goals of senior secondary education and on other official documents related to the curriculum and assessment reform since 2000. including the *Basic Education Curriculum Guide* (2002) and the *Senior Secondary Curriculum Guide* (2009)To gain a full understanding of the connection between education at the senior secondary level and other key stages, and how effective learning, teaching and assessment can be achieved, it is strongly recommended that reference should be made to all related documents.

This C&A Guide is designed to provide the rationale and aims of the subject curriculum, followed by chapters on the curriculum framework, curriculum planning, pedagogy, assessment and use of learning and teaching resources. One key concept underlying the senior secondary curriculum is that curriculum, pedagogy and assessment should be well aligned. While learning and teaching strategies form an integral part of the curriculum and are conducive to promoting learning to learn and whole-person development, assessment should also be recognised not only as a means to gauge performance but also to improve learning. To understand the interplay between these three key components, all chapters in the C&A Guide should be read in a holistic manner.

The C&A Guide was jointly prepared by the Curriculum Development Council (CDC) and the Hong Kong Examinations and Assessment Authority (HKEAA) in 2007. The first updating was made in January 2014 to align with the short-term recommendations made on the senior secondary curriculum and assessment resulting from the New Academic Structure (NAS) review so that students and teachers could benefit at the earliest possible instance. This updating is made to align with the medium-term recommendations of the NAS review made on curriculum and assessment. The CDC is an advisory body that gives recommendations to the HKSAR Government on all matters relating to curriculum development for the school system from kindergarten to senior secondary level. Its

[1] The report is *The New Academic Structure for Senior Secondary Education and Higher Education – Action Plan for Investing in the Future of Hong Kong*, and will be referred to as the *334 Report* hereafter.

membership includes heads of schools, practising teachers, parents, employers, academics from tertiary institutions, professionals from related fields/bodies, representatives from the HKEAA and the Vocational Training Council (VTC), as well as officers from the EDB. The HKEAA is an independent statutory body responsible for the conduct of public assessment, including the assessment for the Hong Kong Diploma of Secondary Education (HKDSE). Its governing council includes members drawn from the school sector, tertiary institutions and government bodies, as well as professionals and members of the business community.

The C&A Guide is recommended by the EDB for use in secondary schools. The subject curriculum forms the basis of the assessment designed and administered by the HKEAA. In this connection, the HKEAA will issue a handbook to provide information on the rules and regulations of the HKDSE Examination as well as the structure and format of public assessment for each subject.

The CDC and HKEAA will keep the subject curriculum under constant review and evaluation in the light of classroom experiences, students' performance in the public assessment, and the changing needs of students and society. All comments and suggestions on this C&A Guide may be sent to:

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Acronym

AL	Advanced Level
ApL	Applied Learning
ASL	Advanced Supplementary Level
C&A	Curriculum and Assessment
CDC	Curriculum Development Council
CE	Certificate of Education
EC	Education Commission
EDB	Education Bureau
HKALE	Hong Kong Advanced Level Examination
HKCAA	Hong Kong Council for Academic Accreditation
HKCEE	Hong Kong Certificate of Education Examination
HKDSE	Hong Kong Diploma of Secondary Education
HKEAA	Hong Kong Examinations and Assessment Authority
HKEdCity	Hong Kong Education City
HKSAR	Hong Kong Special Administrative Region
IT	Information Technology
KLA	Key Learning Area
KS1/2/3/4	Key Stage 1/2/3/4
LOF	Learning Outcomes Framework
MOI	Medium of Instruction
NOS	Nature of Science
NGO	Non-governmental Organisation
OLE	Other Learning Experiences
P1/2/3/4/5/6	Primary 1/2/3/4/5/6
PDP	Professional Development Programmes
QF	Qualifications Framework
RASIH	Review of the Academic Structure for Senior Secondary Education and Interface with Higher Education
S1/2/3/4/5/6	Secondary 1/2/3/4/5/6

SBA	School-based Assessment
SEN	Special Educational Needs
SLP	Student Learning Profile
SRR	Standards-referenced Reporting
STSE	Science, Technology, Society and the Environment
TPPG	Teacher Professional Preparation Grant
VTC	Vocational Training Council

Chapter 1 Introduction

This chapter provides the background, rationale and aims of Physics as an elective subject in the three-year senior secondary curriculum, and highlights how it articulates with the junior secondary curriculum, post-secondary education, and future career pathways.

1.1 Background

The Education Commission's education blueprint for the 21^{st} Century, *Learning for Life, Learning through Life – Reform Proposals for the Education System in Hong Kong* (EC, 2000), highlighted the vital need for a broad knowledge base to enable our students to function effectively in a global and technological society such as Hong Kong, and all subsequent consultation reports have echoed this. The *334 Report* advocated the development of a broad and balanced curriculum emphasising whole-person development and preparation for lifelong learning. Besides the four core subjects, Chinese Language, English Language, Mathematics and Liberal Studies, students are encouraged to select two or three elective subjects from different Key Learning Areas (KLAs) according to their interests and abilities, and also to engage in a variety of other learning experiences such as aesthetic activities, physical activities, career-related experiences, community service, and moral and civic education. This replaces the traditional practice of streaming students into science, arts and technical/commercial subjects.

Study of the three different areas of biology, chemistry and physics often complements and supplements each other. In order to provide a balanced learning experience for students studying sciences, the following elective subjects are offered under the Science Education KLA:

- **Biology**, **Chemistry** and **Physics**
  These subjects are designed to provide a concrete foundation in the respective disciplines for further studies or careers.

- **Science**
  This subject operates in two modes. Mode I, entitled Integrated Science, adopts an interdisciplinary approach to the study of science, while Mode II, entitled Combined Science, adopts a combined approach. The two modes are developed in such a way as to provide space for students to take up elective subjects from other KLAs after taking one or more electives from the Science Education KLA.

Mode I: Integrated Science

This is designed for students wishing to take up one elective subject in the Science Education KLA. It serves to develop in students the scientific literacy essential for participating in a dynamically changing society, and to support other aspects of learning across the school curriculum. Students taking this subject will be provided with a comprehensive and balanced learning experience in the different disciplines of science.

Mode II: Combined Science →
- Combined Science (Physics, Chemistry)
- Combined Science (Biology, Physics)
- Combined Science (Chemistry, Biology)

Students wishing to take two elective subjects in the Science Education KLA are recommended to take one of the Combined Science electives together with one specialised science subject. Each Combined Science elective contains two parts, and these should be the parts that complement the discipline in which they specialise. Students are, therefore, offered three possible combinations:

- Combined Science (Physics, Chemistry) + Biology
- Combined Science (Biology, Physics) + Chemistry
- Combined Science (Chemistry, Biology) + Physics

1.2 Implementation of Science Subjects in Schools

Five separate Curriculum and Assessment Guides for the subjects of Biology, Chemistry, Physics, Integrated Science and Combined Science are prepared for the reference of school managers and teachers, who are involved in school-based curriculum planning, designing learning and teaching activities, assessing students, allocating resources and providing administrative support to deliver the curricula in schools. Arrangements for time-tabling and the deployment of teachers are given in Appendix 1.

This *C&A Guide* sets out the guidelines and suggestions for the Physics Curriculum. The delivery of the Physics part of Combined Science is discussed in the *Combined Science C&A Guide (Secondary 4-6)* (CDC & HKEAA, 2007).

1.3 Rationale

The emergence of a highly competitive and integrated world economy, rapid scientific and technological innovations, and the ever-growing knowledge base will continue to have a profound impact on our lives. In order to meet the challenges posed by these developments, Physics, like other science electives, will provide a platform for developing scientific literacy and the essential scientific knowledge and skills for lifelong learning in science and technology.

Physics is one of the most fundamental natural sciences. It involves the study of universal laws, and of the behaviours and relationships among a wide range of physical phenomena. Through the learning of physics, students will acquire conceptual and procedural knowledge relevant to their daily lives. In addition to the relevance and intrinsic beauty of physics, the study of physics will enable students to develop an understanding of its practical applications in a wide variety of fields. With a solid foundation in physics, students should be able to appreciate both the intrinsic beauty and quantitative nature of physical phenomena, and the role of physics in many important developments in engineering, medicine, economics and other fields of science and technology. Study of the contributions, issues and problems related to innovations in physics will enable students to develop an integrative view of the relationships that hold between science, technology, society and the environment (STSE).

The curriculum attempts to make the study of physics interesting and relevant. It is suggested that the learning of physics should be introduced in real-life contexts. The adoption of a wide range of learning contexts, learning and teaching strategies, and assessment practices is intended to appeal to students of all abilities and aspirations, and to stimulate their interest and motivation for learning. Together with other learning experiences, students are expected to be able to apply their knowledge of physics, to appreciate the relationship between physics and other disciplines, to be aware of the interconnections among science, technology, society and the environment in contemporary issues, and to become responsible citizens.

1.4 Curriculum Aims

The overarching aim of the Physics Curriculum is to provide physics-related learning experiences for students to develop scientific literacy, so that they can participate actively in our rapidly changing knowledge-based society, prepare for further studies or careers in fields related to physics, and become lifelong learners in science and technology.

The broad aims of the curriculum are to enable students to:

- develop interest in the physical world and maintain a sense of wonder and curiosity about it;
- construct and apply knowledge of physics, and appreciate the relationship between physical science and other disciplines;
- appreciate and understand the nature of science in physics-related contexts;
- develop skills for making scientific inquiries;
- develop the ability to think scientifically, critically and creatively, and to solve problems individually or collaboratively in physics-related contexts;
- understand the language of science and communicate ideas and views on physics-related issues;
- make informed decisions and judgments on physics-related issues; and
- be aware of the social, ethical, economic, environmental and technological implications of physics, and develop an attitude of responsible citizenship.

1.5 Interface with the Junior Secondary Curriculum and Post-secondary Pathways

Physics is one of the elective subjects offered in the Science Education KLA. The Physics Curriculum serves as a continuation of the junior secondary Science (S1–3) Curriculum and builds on the strengths of the past Physics Curricula. It will provide a range of balanced learning experiences through which students can develop the necessary scientific knowledge and understanding, skills and processes, and values and attitudes embedded in the strands "Energy and Change" and "The Earth and Beyond". Figure 1.1 depicts how the strands in this KLA are inter-related.

Details about the interface between the junior secondary Science Curriculum and the Physics Curriculum are described in Chapter 3.

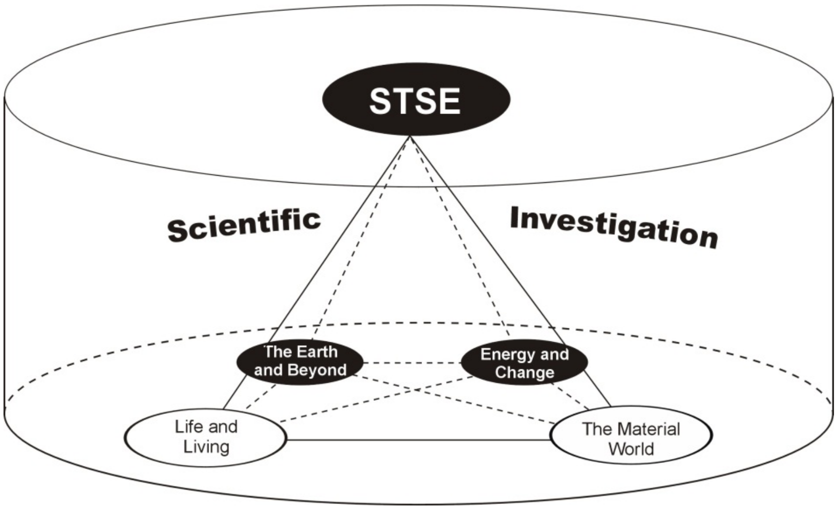


Figure 1.1 Diagrammatic Representation of the Strands in Science Education

The senior secondary academic structure provides a range of pathways to higher education and the workplace so that every student has an opportunity to succeed in life. Figure 1.2 shows the possible pathways.

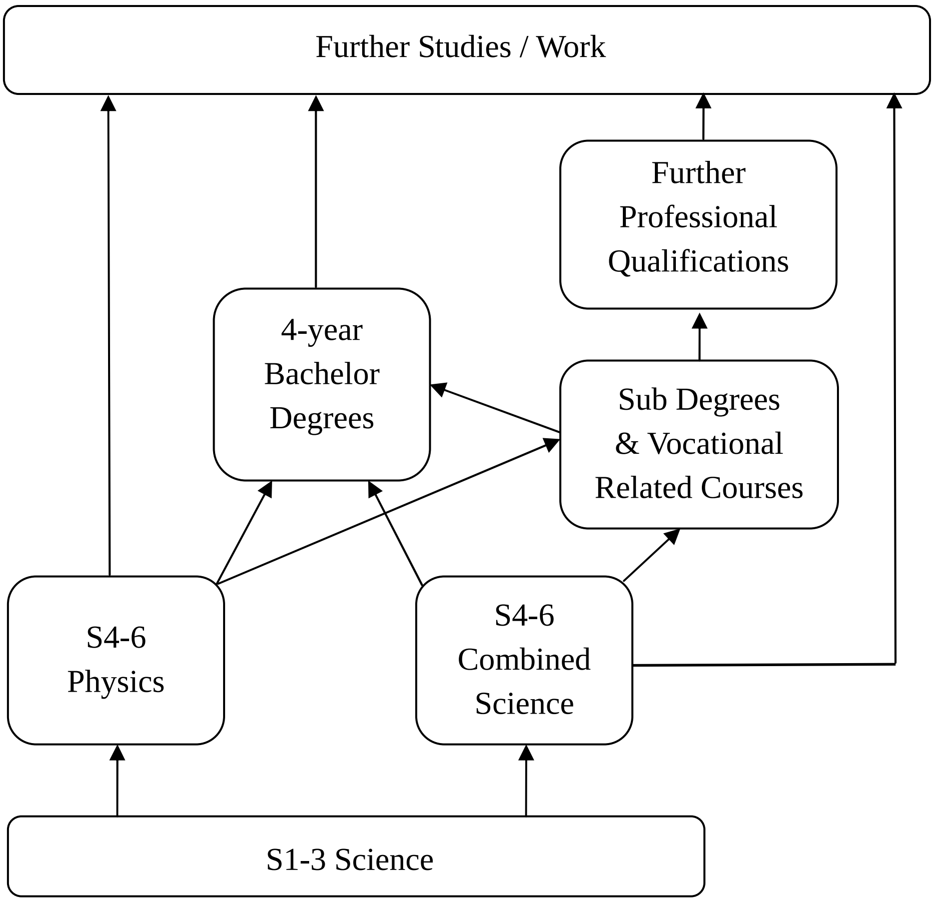


Figure 1.2 Multiple Pathways to Higher Education and the Workplace

This curriculum makes it possible for students to pursue a degree or sub-degree course in a specialised study or other discipline which treasures a good foundation of knowledge and skills in physics, and values and attitudes. The ability to apply physics knowledge and skills to daily life phenomena will enable students to study effectively in a variety of vocational training courses. Furthermore, the development of logical thinking and problem-solving skills among students will be valued in the workplace.

Chapter 2 Curriculum Framework

The curriculum framework for Physics embodies the key knowledge, skills, values and attitudes that students are to develop at senior secondary level. It forms the basis on which schools and teachers can plan their school-based curriculum, and design appropriate learning, teaching and assessment activities.

2.1 Design Principles

The recommendations set out in Chapter 3 of the *334 Report* and Booklet 1 of the *Senior Secondary Curriculum Guide* (CDC, 2009) have been adopted. The following principles are used in the design of the Physics Curriculum framework:

(1) Prior knowledge

This curriculum extends the prior knowledge, skills, values and attitudes, and learning experiences that students will have developed through the junior secondary Science Curriculum. There is a close connection between the topics in the junior secondary Science Curriculum and the Physics Curriculum. Details of this connection are described in Chapter 3.

(2) Balance between breadth and depth

A balanced coverage of topics is selected to broaden students' perspectives. In addition, there will be in-depth study of certain topics to prepare students for further study in a particular area or field of science and technology.

(3) Balance between theoretical and applied learning

Learning of the conceptual knowledge in this curriculum will help students to develop a solid foundation of physics. However, students are also expected to be able to apply the concepts and understand how science, technology, society and the environment are inter-related, so that they may analyse problems in a scientific way for the future.

(4) Balance between essential learning and a flexible and diversified curriculum

The compulsory part of this curriculum will provide students with essential knowledge and concepts, whilst choice in the elective part will allow for flexibility to cater for students with different interests, aspirations and abilities.

(5) Learning how to learn and inquiry-based learning

This curriculum promotes self-directed and lifelong learning through a wide variety of learning and teaching strategies, such as contextual approach, scientific investigations, problem-based learning, issue-based learning and the embedding of learning in real-life contexts. These are also designed to enhance students' understanding of contemporary issues.

(6) Progression

Students can discover what interests them through the study of selected topics within the compulsory part in S4 and then make good choices as they progress through S5 and S6. Details of the progression arrangements are described in Chapter 3.

(7) Smoother articulation to multiple progression pathways

This curriculum enables students to pursue academic and vocational/professional education and training with articulation to a wide range of post-secondary and university study or to the workplace.

(8) Greater coherence

There are cross-curricular elements in the curriculum to strengthen the connections with other subjects.

(9) Catering for diversity

Individual students have different aspirations, abilities, interests and needs. This curriculum provides an opportunity for students to choose elective topics according to their interests and needs. Furthermore, the curriculum is designed to make it possible for students to achieve the learning targets at their own best pace.

(10) Relevance to students' life

Motivation and interest are key considerations for effective and active learning. This curriculum tries to ensure that learning content and activities are relevant to the physical world in which the student lives.

2.2 Learning Targets

The learning targets of this curriculum are categorised into three domains: knowledge and understanding, skills and processes, and values and attitudes. Through the learning embodied in the curriculum, it is intended that students should reach the relevant learning targets.

2.2.1 Knowledge and Understanding

Students are expected to:

- understand phenomena, facts and patterns, principles, concepts, laws, theories and models in physics;
- learn the vocabulary, terminology and conventions used in physics;
- acquire knowledge of techniques and skills specific to the study of physics; and
- develop an understanding of technological applications of physics and of their social implications.

2.2.2 Skills and Processes

(1) Scientific thinking

Students are expected to:

- identify attributes of objects or natural phenomena;
- identify patterns and changes in the natural world and predict trends from them;
- examine evidence and apply logical reasoning to draw valid conclusions;
- present concepts of physics in mathematical terms whenever appropriate;
- appreciate the fundamental role of models in exploring observed natural phenomena;
- appreciate that models are modified as new or conflicting evidence is found;
- examine theories and concepts through logical reasoning and experimentation;
- recognise preconceptions or misconceptions with the aid of experimental evidence; and
- integrate concepts within a framework of knowledge, and apply this to new situations.

(2) Scientific investigation

Students are expected to:

- ask relevant questions;
- propose hypotheses for scientific phenomena and devise methods to test them;
- identify dependent and independent variables in investigations;

- devise plans and procedures to carry out investigations;
- select appropriate methods and apparatus to carry out investigations;
- observe and record experimental observations accurately and honestly;
- organise and analyse data, and infer from observations and experimental results;
- use graphical techniques appropriately to display experimental results and to convey concepts;
- produce reports on investigations, draw conclusions and make further predictions;
- evaluate experimental results and identify factors affecting their quality and reliability; and
- propose plans for further investigations, if appropriate.

(3) Practical work

Students are expected to:

- devise and plan experiments;
- select appropriate apparatus and materials for an experiment;
- follow procedures to carry out experiments;
- handle apparatus properly and safely;
- measure to the precision allowed by the instruments;
- recognise the limitations of instruments used;
- interpret observations and experimental data; and
- evaluate experimental methods and suggest possible improvements.

(4) Problem-solving

Students are expected to:

- clarify and analyse problems related to physics;
- apply knowledge and principles of physics to solve problems;
- suggest creative ideas or solutions to problems;
- propose solution plans and evaluate their feasibility; and
- devise appropriate strategies to deal with issues that may arise.

(5) Decision-making

Students are expected to:

- make decisions based on the examination of evidence and arguments;
- support judgments using appropriate scientific principles; and
- put forward suitable reasoning to choose between alternatives.

(6) Information handling

Students are expected to:

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

(7) Communication

Students are expected to:

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

(8) Collaboration

Students are expected to:

- participate actively, share ideas and offer suggestions in group discussions;
- liaise, negotiate and compromise with others in group work;
- identify collective goals, and define and agree on the roles and responsibilities of members in science projects requiring team work;
- act responsibly to accomplish allocated tasks;
- be open and responsive to ideas and constructive criticism from team members;
- build on the different strengths of members to maximise the potential of the team;
- demonstrate willingness to offer help to less able team members and to seek help from more able members; and
- make use of strategies to work effectively as members of project teams.

(9) Self-directed learning

Students are expected to:

- develop their study skills to improve the effectiveness and efficiency of their learning;
- engage in self-directed learning activities in the study of physics; and
- develop appropriate learning habits, abilities and positive attitudes that are essential to the foundation of lifelong and independent learning.

2.2.3 Values and Attitudes

(1) towards themselves and others

Students are expected to:

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

(2) towards physics and the world we are living in

Students are expected to:

- appreciate achievements in physics and recognise their limitations;
- accept the provisional status of the knowledge and theory of physics;
- apply the knowledge and understanding of physics rationally in making informed decisions or judgments on issues in their daily lives; and
- be aware of the social, economic, environmental and technological implications of the achievements in physics.

(3) towards learning as a lifelong process

Students are expected to:

- recognise the consequences of the evolutionary nature of scientific knowledge and understand that constant updating of knowledge is important in the world of science and technology;
- be exposed to new developments in physics, science and technology and develop an interest in them; and
- recognise the importance of lifelong learning in our rapidly changing knowledge-based society.

Figure 2.1 summarises the learning targets of the curriculum.

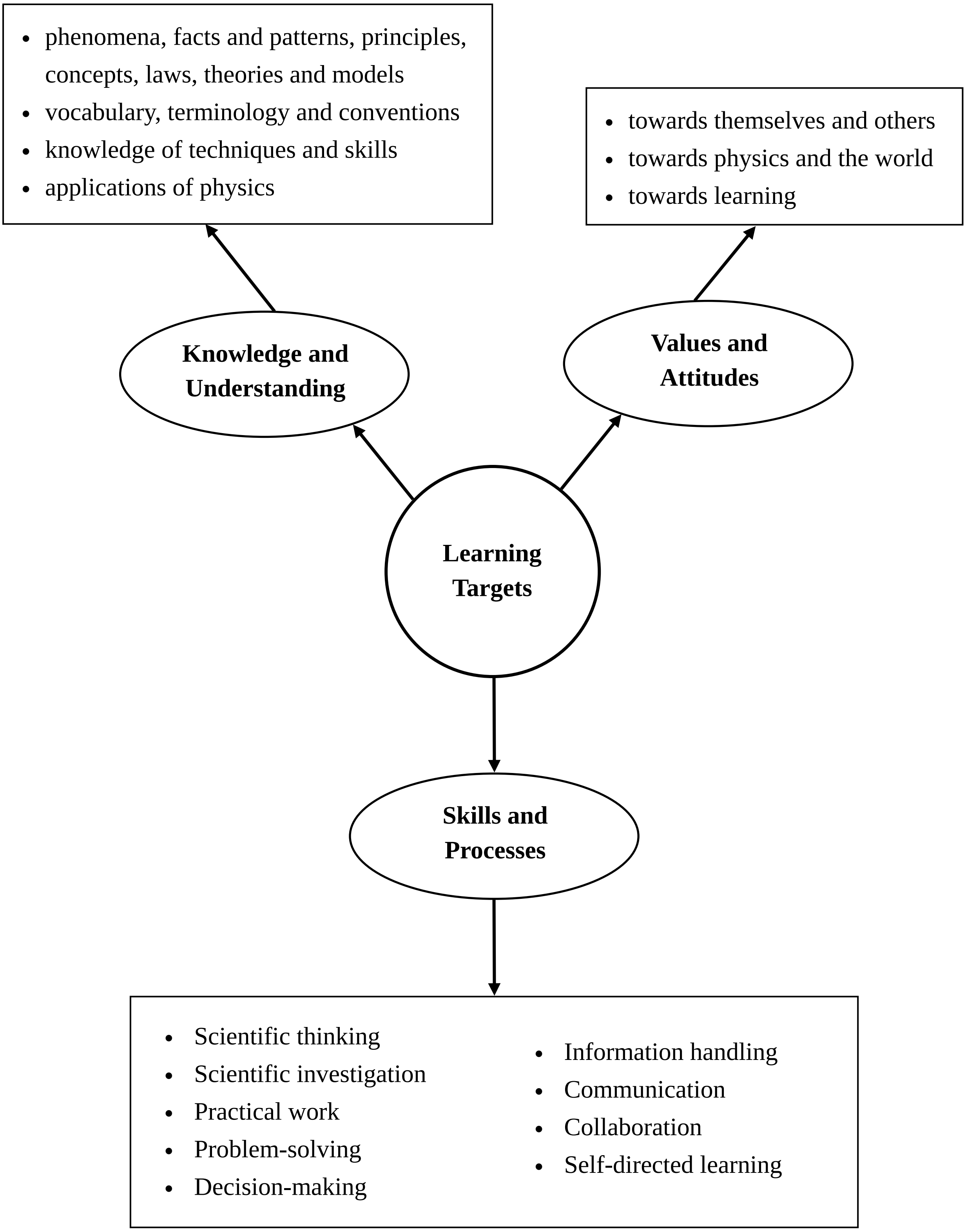


Figure 2.1 Learning Targets of the Physics Curriculum

2.3 Curriculum Structure and Organisation

This curriculum consists of compulsory and elective parts. The compulsory part covers a range of content that enables students to develop understanding of fundamental principles and concepts in physics, and scientific process skills. The following topics: “Heat and Gases”, “Force and Motion”, “Wave Motion”, “Electricity and Magnetism” and “Radioactivity and Nuclear Energy” should be included.

The content of the compulsory part consists of two components, core and extension. The core is the basic component for all students whereas the extension component is generally more cognitively demanding. For some students, it will be more beneficial, less stressful and more effective to concentrate on the core component, so that more time is available for them to master 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 curriculum should have an in-built flexibility to cater for the abilities of students, so that a balance between the quantity and quality of learning may be achieved. However, certain knowledge in the extension component must be introduced to prepare students better for the topics in the elective part.

To cater for the diverse interests, abilities and needs of students, an elective part is included in the curriculum. The elective part aims to provide in-depth treatment of some of the compulsory topics, an extension of certain areas of study, or a synthesis of knowledge, understanding and skills in a particular context. Topics suggested in the elective part are: “Astronomy and Space Science”, “Atomic World”, “Energy and Use of Energy” and “Medical Physics”.

To facilitate the integration of knowledge and skills, students are required to conduct an investigative study relevant to the curriculum. A proportion of the lesson time will be allocated to this study.

The suggested content and time allocation[2] for the compulsory and elective parts are listed in the following tables.

Compulsory part (Total 184 hours)		Suggested lesson time (hours)
I. Heat and Gases	a. Temperature, heat and internal energy* b. Transfer processes* c. Change of state* d. Gases	23
II. Force and Motion	a. Position and movement* b. Force and motion* c. Projectile motion* d. Work, energy and power* e. Momentum* f. Uniform circular motion g. Gravitation	50
III. Wave Motion	a. Nature and properties of waves* b. Light* c. Sound*	47
IV. Electricity and Magnetism	a. Electrostatics* b. Circuits and domestic electricity* c. Electromagnetism*	48
V. Radioactivity and Nuclear Energy	a. Radiation and radioactivity b. Atomic model c. Nuclear energy	16
	Subtotal:	**184**

[2] The lesson time for Liberal Studies and each elective subject is 250 hours (or 10% of the total allocation time) for planning purpose, and schools have the flexibility to allocate lesson time at their discretion in order to enhance learning and teaching effectiveness and cater for students' needs.

"250 hours" is the planning parameter for each elective subject to meet local curriculum needs as well as requirements of international benchmarking. In view of the need to cater for schools with students of various abilities and interests, particularly the lower achievers, "270 hours" was recommended to facilitate schools' planning at the initial stage and to provide more time for teachers to attempt various teaching methods for the NSS curriculum. Based on the calculation of each elective subject taking up 10% of the total allocation time, 2500 hours is the basis for planning the 3-year senior secondary curriculum. This concurs with the reality check and feedback collected from schools in the short-term review, and a flexible range of 2400±200 hours is recommended to further cater for school and learner diversity.

As always, the amount of time spent in learning and teaching is governed by a variety of factors, including whole-school curriculum planning, learners' abilities and needs, students' prior knowledge, teaching and assessment strategies, teaching styles and the number of subjects offered. Schools should exercise professional judgement and flexibility over time allocation to achieve specific curriculum aims and objectives as well as to suit students' specific needs and the school context.

* *Parts of these topics are included in the Physics part of Combined Science (Biology, Physics) and that of Combined Science (Physics, Chemistry) respectively.*

Elective part (Total 50 hours, any 2 out of 4)		**Suggested lesson time (hours)**
VI. Astronomy and Space Science	a. The universe as seen in different scales b. Astronomy through history c. Orbital motions under gravity d. Stars and the universe	25
VII. Atomic World	a. Rutherford's atomic model b. Photoelectric effect c. Bohr's atomic model of hydrogen d. Particles or waves e. Probing into nano scale	25
VIII. Energy and Use of Energy	a. Electricity at home b. Energy efficiency in building and transportation c. Renewable and non-renewable energy sources	25
IX. Medical Physics	a. Making sense of the eye and the ear b. Medical imaging using non-ionizing radiation c. Medical imaging using ionizing radiation	25
	Subtotal:	**50**

Investigative Study (16 hours)		**Suggested lesson time (hours)**
X. Investigative Study in Physics	Students should conduct an investigation with a view to solving an authentic problem	16
	Total lesson time:	**250**

The content of the curriculum is organised into nine topics and an investigative study. The concepts and principles of physics are inter-related. They cannot be confined by any artificial topic boundaries. The order of presentation of the topics in this chapter can be regarded as a possible teaching sequence. However, teachers should adopt sequences that best suit their chosen teaching approaches and benefit student learning. For instance, an earlier topic can be integrated with a later one, or some parts of a certain topic may be covered in advance if they fit naturally in a chosen context. Details about suggested learning and teaching sequences are described in Chapter 3.

There are five major parts in each of the following nine topics:

Overview – This part outlines the main theme of the topic. The major concepts and important physics principles to be acquired are highlighted. The focuses of each topic are briefly described and the interconnections between subtopics are also outlined.

Students Should Learn and Should be Able to – This part lists out the intentions of learning (students should learn) and learning outcomes (students should be able to) to be acquired by students in the knowledge content domain of the curriculum. It provides a broad framework upon which learning and teaching activities can be developed. General principles and examples of learning and teaching strategies are described in Chapter 4.

Suggested Learning and Teaching Activities – This part gives suggestions on some of the different skills that are expected to be acquired in the topic. Some important processes associated with the topic are also briefly described. Most of the generic skills can be acquired through activities associated with any of the topics. In fact, students need to acquire a much broader variety of skills than are mentioned in the topics. Teachers should exercise their professional judgment to arrange practical and learning activities to develop the skills of students as listed in the Learning Targets in this chapter. This should be done through appropriate integration with knowledge content, taking students' abilities and interests and school context into consideration. Learning and teaching strategies are further discussed in Chapter 4.

Values and Attitudes – This part suggests some positive values and attitudes that can be promoted through study of particular topics. Students are expected to develop such values and attitudes in the course of studying physics. Through discussions and debates, for example, students are encouraged to form value judgments and develop good habits.

STSE connections – This part suggests issue-based learning activities and contexts related to the topics. Students should be encouraged to develop an awareness and comprehension of issues which highlight the interconnections among science, technology, society and the environment. Through discussions, debates, information search and project work, students can develop their skills of communication, information handling, critical thinking and informed judgment. Teachers are free to select other topics and issues of great current interest to generate other meaningful learning activities.

2.3.1 Compulsory Part (184 hours)

I Heat and Gases (23 hours)

Overview

This topic examines the concept of thermal energy and transfer processes which are crucial for the maintenance and quality of our lives. Particular attention is placed on the distinction and relationships among temperature, internal energy and energy transfer. Students are also encouraged to adopt microscopic interpretations of various important concepts in the topic of thermal physics.

Calculations involving specific heat capacity will serve 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 experience 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 specific latent heat are used to consolidate the theoretical aspects of energy conversion.

The ideal gas law relating the pressure, temperature and volume of an ideal gas was originally derived from the experimentally measured Charles' law and Boyle's law. Many common gases exhibit behaviour very close to that of an ideal gas at ambient temperature and pressure. The ideal gas law is a good approximation for studying the properties of gases because it does not deviate much from the ways that real gases behave. The kinetic theory of gases is intended to correlate temperature to the kinetic energy of gas molecules and interpret pressure in terms of the motion of gas molecules.

Students should learn:	Students should be able to:
a. Temperature, heat and internal energy	
temperature and thermometers	• realise temperature as the degree of hotness of an object • interpret temperature as a quantity associated with the average kinetic energy due to the random motion of molecules in a system • explain the use of temperature-dependent properties in measuring temperature • define and use degree Celsius as a unit of temperature
heat and internal energy	• realise that heat is the energy transferred as a result of the temperature difference between two objects • describe the effect of mass, temperature and state of matter on the internal energy of a system • relate internal energy to the sum of the kinetic energy of random motion and the potential energy of molecules in the system
heat capacity and specific heat capacity	• define heat capacity as $C = \frac{Q}{\Delta T}$ and specific heat capacity as $c = \frac{Q}{m\Delta T}$ • determine the specific heat capacity of a substance • discuss the practical importance of the high specific heat capacity of water • solve problems involving heat capacity and specific heat capacity
b. Transfer processes	
conduction, convection and radiation	• identify the means of energy transfer in terms of conduction, convection and radiation • interpret energy transfer by conduction in terms of molecular motion • realise the emission of infra-red radiation by hot objects • determine the factors affecting the emission and absorption of radiation

Students should learn:	Students should be able to:
c. Change of state	
melting and freezing, boiling and condensing	• state the three states of matter • determine the melting point and boiling point
latent heat	• realise latent heat as the energy transferred during the change of state without temperature change • interpret latent heat in terms of the change of potential energy of the molecules during a change of state • define specific latent heat of fusion as $\ell_f = \frac{Q}{m}$ • define specific latent heat of vaporization as $\ell_v = \frac{Q}{m}$ • solve problems involving latent heat
evaporation	• realise the occurrence of evaporation below boiling point • explain the cooling effect of evaporation • discuss the factors affecting rate of evaporation • explain evaporation in terms of molecular motion
d. Gases	
general gas law	• realise the existence of gas pressure • verify Boyle's law • determine pressure-temperature and volume-temperature relationships of a gas • determine absolute zero by the extrapolation of pressure-temperature or volume-temperature relationships • use kelvin as a unit of temperature • combine the three relationships (p-V, p-T and V-T) of a gas to obtain the relationship $\frac{pV}{T} = \text{constant}$ • apply the general gas law $pV = nRT$ to solve problems
kinetic theory	• realise the random motion of molecules in a gas • realise the gas pressure resulted from molecular bombardment • interpret gas expansion in terms of molecular motion

Students should learn:	Students should be able to:
	• state the assumptions of the kinetic model of an ideal gas • realize $pV = \frac{Nm\overline{c^2}}{3}$ that connects micropic and macroscopic quantities of an ideal gas and solve problems • interpret temperature of an ideal gas using $K.E._{average} = \frac{3RT}{2N_A}$ • realise the condition that at high temperature and low pressure a real gas behaves as an ideal gas • solve problems involving kinetic theory

(Note: The underlined text represents the extension component)

Suggested Learning and Teaching Activities

Students should develop experimental skills in measuring temperature, volume, pressure and energy of a gas. The precautions essential for accurate measurements in heat experiments should be understood in terms of the concepts learned in this topic. Students should also be encouraged to suggest their own methods for improving the accuracy of these experiments, and arrangement for performing these investigations should be made, if feasible. In some of the experiments, a prior knowledge of electrical energy may be required for a solid understanding of the energy transfer processes involved.

Considerable emphasis is given to the importance of graphical representations of physical phenomena in this topic. Students should learn how to plot graphs with suitable choices of scales, display experimental results graphically and interpret, analyse and draw conclusions from graphical information. In particular, they should learn to extrapolate the trends of the graphs to determine the absolute zero of the temperature. Students should be able to plan and interpret information from different types of data sources. Most experiments and investigations will produce a set of results which can readily be compared with data in textbooks and handbooks.

Possible learning activities that students may engage in are suggested below for reference:

- Studying the random motion of molecules inside a smoke cell using a microscope and video camera

- Performing an experiment to show how to measure temperature using a device with temperature-dependent properties
- Calibrating a thermometer
- Reproducing fixed points on the Celsius scale
- Performing experiments to determine specific heat capacity and latent heat
- Measuring the specific latent heat of fusion of water (e.g. using a domestic electric boiler, heating an ice-water mixture in a composite container, or using an ice calorimeter)
- Performing experiments to study the cooling curve of a substance and determine its melting point
- Performing experiments to study the relationship among volume, pressure and temperature of a gas
- Determining factors affecting the rate of evaporation
- Feeling the sensation of coldness by touching a few substances in the kitchen and clarifying some misconceptions that may arise from their daily experience
- Studying conduction, convection, radiation, the greenhouse effect and heat capacity by designing and constructing a solar cooker
- Challenging their preconceived ideas on energy transfer through appropriate competitions (e.g. attaining a temperature closest to $4^{o}C$ by mixing a soft drink with ice)
- Using dimension analysis to check the results of mathematical solutions
- Investigating the properties of a gas using simulations or modelling
- Reading articles on heat stroke and discussing heat stroke precautions and care

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to be aware of the proper use of heat-related domestic appliances as this 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 the transfer of heat and to develop good habits in using air-conditioning in summer and heating in winter
- to develop an interest in using alternative environmentally friendly energy sources such as solar 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 daily life

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the importance of greenhouses in agriculture and the environmental issues of the "greenhouse effect"
- debates on the gradual rise in global temperature due to human activities, the associated potential global hazards 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 Cooker", to develop investigation skills as well as foster the concept of using alternative environmentally friendly energy sources

II Force and Motion (50 hours)

Overview

Motion is a common phenomenon in our daily experience. It is an important element in physics where students learn to describe how objects move and investigate why objects move in the way that they do. In this topic, the fundamentals of mechanics in kinematics and dynamics are introduced, and the foundation for describing motion with physics terminology is laid. Various types of graphical representation 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 about motion in one or two dimensions and rules governing the motion of objects on Earth.

The concept of inertia and its relation to Newton's First Law of motion are covered. Simple addition and resolution of forces are used to illustrate the vector properties of forces. 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 study of motion is extended to two dimensions, including projectile motion and circular motion which lead to an investigation of gravitation.

Work is a process of energy transfer. The concepts of mechanical work done and energy transfer are examined and used in the derivation of kinetic energy and gravitational potential energy. Conservation of energy in a closed system is a fundamental concept in physics. The treatment of energy conversion is used to illustrate the law of conservation of energy, and the concept of power is also introduced. Students learn how to compute quantities such as momentum and energy in examples involving collisions. The relationship among the change in the momentum of a body, impact time and impact force is emphasised.

Students should learn:	**Students should be able to:**
a. Position and movement	
position, distance and displacement	• describe the change of position of objects in terms of distance and displacement • present information on displacement-time graphs for moving objects
scalars and vectors	• distinguish between scalar and vector quantities • use scalars and vectors to represent physical quantities
speed and velocity	• define average speed as the distance travelled in a given period of time and average velocity as the displacement changed in a period of time • distinguish between instantaneous and average speed/velocity • describe the motion of objects in terms of speed and velocity • present information on velocity-time graphs for moving objects • use displacement-time and velocity-time graphs to determine the displacement and velocity of objects
uniform motion	• interpret the uniform motion of objects using algebraic and graphical methods • solve problems involving displacement, time and velocity
acceleration	• define acceleration as the rate of change of velocity • use velocity-time graphs to determine the acceleration of objects in uniformly accelerated motion • present information on acceleration-time graphs for moving objects
equations of uniformly accelerated motion	• derive equations of uniformly accelerated motion $v = u + at$ $s = \frac{1}{2}(u + v)t$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ • solve problems involving objects in uniformly accelerated motion

Students should learn:	Students should be able to:
vertical motion under gravity	• examine the motion of free-falling objects experimentally and estimate the acceleration due to gravity • present graphically information on vertical motions under gravity • apply equations of uniformly accelerated motion to solve problems involving objects in vertical motion • describe the effect of air resistance on the motion of objects falling under gravity
b. Force and motion	
Newton's First Law of motion	• describe the meaning of inertia and its relationship to mass • state Newton's First Law of motion and use it to explain situations in which objects are at rest or in uniform motion • understand friction as a force opposing motion/tendency of motion
addition and resolution of forces	• find the vector sum of coplanar forces graphically and algebraically • resolve a force graphically and algebraically into components along two mutually perpendicular directions
Newton's Second Law of motion	• describe the effect of a net force on the speed and/or direction of motion of an object • state Newton's Second Law of motion and verify $F = ma$ experimentally • use newton as a unit of force • use free-body diagrams to show the forces acting on objects • determine the net force acting on object(s) • apply Newton's Second Law of motion to solve problems involving motion in one dimension
Newton's Third Law of motion	• realise forces acting in pairs • state Newton's Third Law of motion and identify action and reaction pair of forces

Students should learn:	Students should be able to:
mass and weight	• distinguish between mass and weight • realise the relationship between mass and weight
moment of a force	• define moment of a force as the product of the force and its perpendicular distance from the pivot • discuss the uses of torques and couples • state the conditions for equilibrium of forces acting on a rigid body and solve problems involving a fixed pivot • interpret the centre of gravity and determine it experimentally
c. <u>Projectile motion</u>	• <u>describe the shape of the path taken by a projectile launched at an angle of projection</u> • <u>understand the independence of horizontal and vertical motions</u> • <u>solve problems involving projectile motion</u>
d. Work, energy and power	
mechanical work	• interpret mechanical work as a way of energy transfer • define mechanical work done $W = Fs\cos\theta$ • solve problems involving mechanical work
gravitational potential energy (P.E.)	• state that gravitational potential energy is the energy possessed by an object due to its position under gravity • derive $P.E. = mgh$ • solve problems involving gravitational potential energy
kinetic energy (K.E.)	• state that kinetic energy is the energy possessed by an object due to its motion • derive $K.E. = \frac{1}{2}mv^2$ • solve problems involving kinetic energy
law of conservation of energy in a closed system	• state the law of conservation of energy • discuss the inter-conversion of P.E. and K.E. with consideration of energy loss • solve problems involving conservation of energy

Students should learn:	Students should be able to:
power	• define power as the rate of energy transfer • apply $P = \frac{W}{t}$ to solve problems
e. Momentum	
linear momentum	• realise momentum as a quantity of motion of an object and define momentum $p = mv$
change in momentum and net force	• understand that a net force acting on an object for a period of time results a change in momentum • interpret force as the rate of change of momentum (Newton's Second Law of motion)
law of conservation of momentum	• state the law of conservation of momentum and relate it to Newton's Third Law of motion • distinguish between elastic and inelastic collisions • solve problems involving momentum in one dimension
f. <u>Uniform circular motion</u>	• <u>define angular velocity as the rate of change of angular displacement and relate it to linear velocity</u> • <u>state centripetal acceleration $a = \frac{v^2}{r}$ and apply it to solve problem involving uniform circular motion</u> • <u>realise the resultant force pointing towards the centre of uniform circular motion</u>
g. <u>Gravitation</u>	• <u>state Newton's law of universal gravitation $F = \frac{GMm}{r^2}$</u> • <u>define gravitational field strength as force per unit mass</u> • <u>determine the gravitational field strength at a point above a planet</u> • <u>determine the velocity of an object in a circular orbit</u> • <u>solve problems involving gravitation</u>

(Note: The underlined text represents the extension component)

Suggested Learning and Teaching Activities

Students should develop experimental skills in measuring time and in recording the positions, velocities and accelerations of objects using various types of measuring instruments such as stop watches and data logging sensors. Skills in measuring masses, weights and forces are also required. Data-handling skills such as converting data of displacement and time into information on velocity or acceleration are important. Students may be encouraged to carry out project-type investigations on the motion of vehicles. Considerable emphasis is placed on the importance of graphical representations of physical phenomena in this topic. Students should learn how to plot graphs with a suitable choice of scale, 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. Students should be able to plan and interpret information from different types of data source. Most experiments and investigations will produce a set of results which may readily be compared with data in textbooks and handbooks.

Possible learning activities that students may engage in are suggested below for reference:

- Performing experiments on motion and forces (e.g. using ticker-tape timers, multi-flash photography, video motion analysis and data loggers) and a graphical analysis of the results
  - Using light gates or motion sensors to measure the speed and acceleration of a moving object
  - Inferring the relationships among acceleration, velocity, displacement and time from a graphical analysis of empirical data for uniformly accelerated motion
  - Using light gates or motion sensors to measure the acceleration due to gravity
  - Using light gates or motion sensors to determine the factors affecting acceleration
  - Using force and motion sensors to determine the relationship among force, mass and acceleration
  - Using multi-flash photography or a video camera to analyse projectile motion or circular motion
  - Using force sensors to determine the relationship among radius, angular speed and the centripetal force on an object moving in a circle
- Performing experiments on energy and momentum (e.g. colliding dynamic carts, gliders on air tracks, pucks on air tables, rolling a ball-bearing down an inclined plane, dropping a mass attached to a spring)
  - Using light gates or motion sensors to measure the change of momentum during a collision

  - Using light gates or motion sensors and air track to investigate the principle of conservation of linear momentum
  - Using force sensors to measure the impulse during collision
- Performing experiments to show the independence of horizontal and vertical motions under the influence of gravity
- Performing experiments to investigate the relationships among mechanical energy, work and power
- Determining the output power of an electric motor by measuring the rate of energy transfer
- Estimating the work required for various tasks, such as lifting a book, stretching a spring and climbing Lantau Peak
- Estimating the K.E. of various moving objects such as a speeding car, a sprinter and an air molecule
- Investigating the application of conservation principles in designing energy transfer devices
- Evaluating the design of energy transfer devices, such as household appliances, lifts, escalators and bicycles
- Using free-body diagrams in organising and presenting the solutions of dynamic problems
- Tackling problems that, even if a mathematical treatment is involved, have a direct relevance to their experience (e.g. sport, transport and skating) in everyday life and exploring solutions of problems related to these experiences
- Using dimension analysis to check the results of mathematical solutions
- Challenging their preconceived ideas on motion and force by posing appropriate thought-provoking questions (e.g. “zero” acceleration at the maximum height and “zero” gravitational force in space shuttle)
- Increasing their awareness of the power and elegance of the conservation laws by contrasting such solutions with those involving the application of Newton’s Second Law of motion.
- Investigating motion in a plane using simulations or modelling (http://modellus.co/index.php/en/)
- Using the Ocean Park Hong Kong as a large laboratory to investigate laws of motion and develop numerous concepts in mechanics from a variety of experiences at the park (http://www.hk-phy.org/oceanpark/index.html)

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to be aware of the importance of car safety and be committed to safe practices in their daily life
- to be aware of the potential danger of falling objects from high-rise buildings and to adopt a cautious attitude in matters concerning public safety
- to be aware of the environmental implications of different modes of transport and to make an effort to reduce energy consumption in daily life
- to accept uncertainty in the description and explanation of motions in the physical world
- to be open-minded in evaluating potential applications of principles in mechanics to new technology
- to appreciate the efforts made by scientists to find alternative environmentally friendly energy sources
- to appreciate that the advances in important scientific theories (such as Newton's laws of motion) can ultimately have a huge impact on technology and society
- to appreciate the contributions of Galileo and Newton that revolutionised the scientific thinking of their time
- to appreciate the roles of science and technology in the exploration of outer-space and the efforts of humankind in the quest to understand nature

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic 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
- penalising drivers and passengers who do not wear seatbelts and raising 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
- the use of principles in mechanics in traffic accident investigations

- modern transportation: the dilemma in choosing between speed and safety; and between convenience and environmental protection
- evaluating the technological design of modern transport (e.g. airbags in cars, tread patterns on car tyres, hybrid vehicles, magnetically levitated trains)
- the use of technological devices including terrestrial and space vehicles (e.g. Shenzhou spacecraft)
- enhancement of recreational activities and sports equipment
- the ethical issue of dropping objects from high-rise buildings and its potential danger as the principles of physics suggest
- careers that require an understanding and application of kinematics and dynamics

III Wave Motion (47 hours)

Overview

This topic examines the basic nature and properties of waves. Light and sound, in particular, are also studied in detail. Students are familiar with examples of energy being transmitted from one place to another, together with the transfer of matter. In this topic, the concept of waves as a means of transmitting energy without transferring matter is emphasised. The foundations for describing wave motion with physics terminology are 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 specific knowledge about light in two important aspects. The characteristics of light as a part of the electromagnetic spectrum are studied. Also, the linear propagation of light in the absence of significant diffraction and interference effects is used to explain image formation in the domain of geometrical optics. The formation of real and virtual images using mirrors and lenses is studied with construction rules for light rays.

Sound as an example of longitudinal waves is examined and 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 terminology of waves. The effects of noise pollution and the importance of acoustic protection are also studied.

Students should learn:	Students should be able to:
a. Nature and properties of waves	
nature of waves	• interpret wave motion in terms of oscillation • realise waves as transmitting energy without transferring matter

Students should learn:	Students should be able to:
wave motion and propagation	• distinguish between transverse and longitudinal waves • describe wave motion in terms of waveform, crest, trough, compression, rarefaction, wavefront, phase, displacement, amplitude, period, frequency, wavelength and wave speed • present information on displacement-time and displacement-distance graphs for travelling waves • determine factors affecting the speed of propagation of waves along stretched strings or springs • apply $f = \frac{1}{T}$ and $v = f\lambda$ to solve problems
reflection and refraction	• realise the reflection of waves at a plane barrier/reflector/surface • realise the refraction of waves across a plane boundary • examine the change in wave speeds during refraction and define refractive index in terms of wave speeds • draw wavefront diagrams to show reflection and refraction
diffraction and interference	• describe the diffraction of waves through a narrow gap and around a corner • examine the effect of the width of slit on the degree of diffraction • describe the superposition of two pulses • realise the interference of waves • distinguish between constructive and destructive interferences • examine the interference of waves from two coherent sources • determine the conditions for constructive and destructive interferences in terms of path difference • draw wavefront diagrams to show diffraction and interference
stationary wave (transverse waves only)	• explain the formation of a stationary wave • describe the characteristics of stationary waves

Students should learn:	Students should be able to:
b. Light	
light in electromagnetic spectrum	• state that the speed of light and electromagnetic waves in a vacuum is 3.0×10^8 m s^{-1} • state the range of wavelengths for visible light • state the relative positions of visible light and other parts of the electromagnetic spectrum
reflection of light	• state the laws of reflection • construct images formed by a plane mirror graphically
refraction of light	• examine the laws of refraction • sketch the path of a ray refracted at a boundary • realise $n = \frac{\sin i}{\sin r}$ as the refractive index of a medium • solve problems involving refraction at a boundary
total internal reflection	• examine the conditions for total internal reflection • solve problems involving total internal reflection at a boundary
formation of images by lenses	• construct images formed by converging and diverging lenses graphically • distinguish between real and virtual images • apply $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ to solve problems for a single thin lens (using the convention "REAL is positive")
wave nature of light	• point out light as an example of transverse wave • realise diffraction and interference as evidences for the wave nature of light • examine the interference patterns in the Young's double slit experiment • apply $\Delta y = \frac{\lambda D}{a}$ to solve problems

Students should learn:	**Students should be able to:**
	• examine the interference patterns in the plane transmission grating • <u>apply $d\sin\theta = n\lambda$ to solve problems</u>

c. Sound

wave nature of sound	• realise sound as an example of longitudinal waves • realise that sound can exhibit reflection, refraction, diffraction and interference • realise the need for a medium for sound transmission • compare the general properties of sound waves and those of light waves
audible frequency range	• determine the audible frequency range • examine the existence of ultrasound beyond the audible frequency range
musical notes	• compare musical notes using pitch, loudness and quality • relate frequency and amplitude with the pitch and loudness of a note respectively
noise	• represent sound intensity level using the unit decibel • discuss the effects of noise pollution and the importance of acoustic protection

(Note: The underlined text represents the extension component)

Suggested Learning and Teaching Activities

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 the CRO or the computer. They should appreciate that scientific evidence is obtained through indirect measurement 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 geometrical optics for image formation and the wave model of light is used to explain phenomena such as diffraction and interference. Through the study of the physics of musical notes, students understand that most everyday experiences can be explained using scientific concepts.

Possible learning activities that students may engage in are suggested below for reference:

- Investigating the properties of waves generated in springs and ripple tanks
- Investigating factors affecting the speed of transverse progressive waves along a slinky spring
- Determining the speed of a water wave in a ripple tank or a wave pulse travelling along a stretched spring or string
- Demonstrating the superposition of transverse waves on a slinky spring
- Using CRO waveform demonstrations to show the superposition of waves
- Drawing the resultant wave when two waves interfere by using the principle of superposition
- Estimating the wavelength of light by using double slit or plane transmission grating
- Estimating the wavelength of microwaves by using double slit
- Demonstrating interference patterns in soap film
- Determining the effects of wavelength, slit separation or screen distance on an interference pattern in an experiment by using double slit
- Measuring the focal lengths of lenses
- Locating real and virtual images in lenses by using ray boxes and ray tracing
- Using ray diagrams to predict the nature and position of an image in an optical device
- Searching for information on the development of physics of light
- Discussing some everyday uses and effects of electromagnetic radiation
- Using computer simulations to observe and investigate the properties of waves
- Investigating the relationship between the frequency and wavelength of a sound wave
- Carrying out an experiment to verify Snell’s law
- Determining the refractive index of glass or perspex

- Determining the conditions for total internal reflection to occur
- Identifying the differences between sounds in terms of loudness, pitch and quality
- Using dimension analysis to check the results of mathematical solutions

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- 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) is the fruit of the hard work of generations of scientists who devoted themselves to scientific investigations by applying their intelligence, knowledge and skills
- to be aware of the potential health hazards of a prolonged exposure to extreme noise 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 daily life

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic 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 of increased ultra-violet radiation from the Sun on the human body as a result of the depletion of the atmospheric ozone layer by artificial pollutants
- the problem of noise pollution in the local context
- the impact on society of the scientific discovery of electromagnetic waves and the technological advances in the area of telecommunications
- how major breakthroughs in scientific and technological development that eventually

affect society are associated with new understanding of fundamental physics as illustrated by the study of light in the history of science

- how technological advances can provide an impetus for scientific investigations as demonstrated in the invention and development of the microscope, telescope and X-ray diffraction, with these scientific investigations in turn shedding light on our own origin and the position of humankind in the universe

IV Electricity and Magnetism (48 hours)

Overview

This topic examines the basic principles of electricity and magnetism. The abstract concept of an electric field is introduced through its relationship with the electrostatic force. The inter-relationships among voltage, current, resistance, charge, energy and power are examined and the foundation for basic circuitry is laid. As electricity is the main energy source in homes and electrical appliances have become an integral part of daily life, the practical use of electricity in households is studied. Particular attention is paid to the safety aspects of domestic electricity.

The concept of magnetic field is applied to the study of electromagnetism. The magnetic effects of electric current and some simple magnetic field patterns are studied. Students also learn the factors that affect the strength of an electromagnet. A magnetic force is produced when a current-carrying conductor is placed in a magnetic field. An electric motor requires the supply of electric current to the coil in a magnetic field to produce a turning force causing it to rotate.

The general principles of electromagnetic induction are introduced. Electrical energy can be generated when there is relative motion between a conductor and a magnetic field. Generators reverse the process in motors to convert mechanical energy into electrical energy. The operation of simple d.c. and a.c. generators are studied. Students learn how a.c. voltages can be stepped up or down with transformers. The system by which electrical energy is transmitted over great distances to our homes is also studied.

Students should learn:	**Students should be able to:**
a. Electrostatics	
electric charges	• examine the evidence for two kinds of charges in nature • realise the attraction and repulsion between charges • state Coulomb's law $F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$ • interpret charging in terms of electron transfer • solve problems involving forces between point charges

Students should learn:	Students should be able to:
electric field	• describe the electric field around a point charge and between parallel charged plates • represent an electric field using field lines • explain how charges interact via an electric field • define electric field strength E at a point as the force per unit charge on a positive test charge placed at that point • state electric field strength around a point charge by $E = \frac{Q}{4\pi\varepsilon_o r^2}$ and between parallel plates by $E = \frac{V}{d}$, and solve problems
b. Circuits and domestic electricity	
electric current	• define electric current as the rate of flow of electric charges • state the convention for the direction of electric current
electrical energy and electromotive force	• describe the energy transformations in electric circuits • define the potential difference (p.d.) between two points in a circuit as the electric potential energy converted to other forms per unit charge passing between the points outside the source • define the electromotive force (e.m.f.) of a source as the energy imparted by the source per unit charge passing through it
resistance	• define resistance $R = \frac{V}{I}$ • describe the variation of current with applied p.d. in metal wires, electrolytes, filament lamps and diodes • realise Ohm's law as a special case of resistance behaviour • determine the factors affecting the resistance of a wire and define its resistivity $\rho = \frac{RA}{l}$

Students should learn:	Students should be able to:
	• describe the effect of temperature on resistance of metals and semiconductors
series and parallel circuits	• compare series and parallel circuits in terms of p.d. across the components of each circuit and the current through them • derive the resistance combinations in series and parallel $R = R_1 + R_2 + \ldots\ldots$ for resistors connected in series $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$ for resistors connected in parallel
simple circuits	• measure I, V and R in simple circuits • assign the electrical potential of any earthed points as zero • compare the e.m.f. of a source and the terminal voltage across the source experimentally and relate the difference to the internal resistance of the source • explain the effects of resistance of ammeters and voltmeters on measurements • solve problems involving simple circuits
electrical power	• examine the heating effect when a current passes through a conductor • apply $P = VI$ to solve problems
domestic electricity	• determine the power rating of electrical appliances • use kilowatt-hour (kW h) as a unit of electrical energy • calculate the costs of running various electrical appliances • understand household wiring and discuss safety aspects of domestic electricity • determine the operating current for electrical appliances • discuss the choice of power cables and fuses for electrical appliances based on the power rating

Students should learn:	Students should be able to:
c. Electromagnetism	
magnetic force and magnetic field	• realise the attraction and repulsion between magnetic poles • examine the magnetic field in the region around a magnet • describe the behaviour of a compass in a magnetic field • represent magnetic field using field lines
magnetic effect of electric current	• realise the existence of a magnetic field due to moving charges or electric currents • examine the magnetic field patterns associated with currents through a long straight wire, a circular coil and a long solenoid • apply $B = \frac{\mu_o I}{2\pi r}$ and $B = \frac{\mu_o NI}{l}$ to represent the magnetic fields around a long straight wire, and inside a long solenoid carrying current, and solve related problems • examine the factors affecting the strength of an electromagnet
force due to magnetic field	• examine the existence of a force on a current-carrying conductor in a magnetic field and determine the relative directions of force, field and current • determine the factors affecting the force on a straight current-carrying wire in a magnetic field and represent the force by $F = BIl \sin\theta$ • determine the turning effect on a current-carrying coil in a magnetic field • describe the structure of a simple d.c. motor and how it works • solve problems involving current-carrying conductors in a magnetic field • represent the force on a moving charge in a magnetic field by $F = BQv \sin\theta$ and solve problems
electromagnetic induction	• examine induced e.m.f. resulting from a moving conductor in a steady magnetic field or a stationary conductor in a changing magnetic field

Students should learn:	Students should be able to:
	• apply Lenz's law to determine the direction of induced e.m.f./current • <u>define magnetic flux $\Phi = BA\cos\theta$ and weber (Wb) as a unit of magnetic flux</u> • <u>interpret magnetic field B as magnetic flux density</u> • <u>state Faraday's Law as $\varepsilon = -\frac{\Delta\Phi}{\Delta t}$ and apply it to calculate the average induced e.m.f.</u> • <u>examine magnetic fields using a search coil</u> • describe the structures of simple d.c. and a.c. generators and how they work • discuss the occurrence and practical uses of eddy currents
<u>alternating currents (a.c.)</u>	• <u>distinguish between direct currents (d.c.) and alternating currents (a.c.)</u> • <u>define r.m.s. of an alternating current as the steady d.c. which converts electric potential energy to other forms in a given pure resistance at the same rate as that of the a.c.</u> • <u>relate the r.m.s. and peak values of an a.c.</u>
<u>transformer</u>	• <u>describe the structure of a simple transformer and how it works</u> • <u>relate the voltage ratio to turn ratio by $\frac{V_P}{V_S} = \frac{N_P}{N_S}$ and apply it to solve problems</u> • <u>examine methods for improving the efficiency of a transformer</u>
<u>high voltage transmission of electrical energy</u>	• <u>discuss the advantages of transmission of electrical energy with a.c. at high voltages</u> • <u>describe various stages of stepping up and down of the voltage in a grid system for power transmission</u>

(Note: The underlined text represents the extension component)

Suggested Learning and Teaching Activities

Students should develop experimental skills in connecting up circuits. They are required to perform electrical measurements using various types of equipment, such as galvanometer, ammeter, voltmeter, multi-meter, joulemeter, CRO and data logging sensors. Students should acquire the skills in performing experiments to study, demonstrate and explore concepts of physics, such as electric fields, magnetic fields and electromagnetic induction. Students can gain practical experience 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. Handling apparatus properly and safely is a very basic practical skill of great importance.

Possible learning activities that students may engage in are suggested below for reference:

- Showing the nature of attraction and repulsion using simple electrostatic generation and testing equipment
- Investigating the nature of the electric field surrounding charges and between parallel plates
- Plotting electric field lines by using simple measurement of equipotentials in the field
- Measuring current, e.m.f., and potential difference around the circuit by using appropriate meters and calculating the resistance of any unknown resistors
- Verifying Ohm's law by finding the relationship between p.d. across a resistor and current passing through it
- Determining factors affecting the resistance of a resistor
- Comparing the changing resistance of ohmic devices, non-ohmic devices and semiconductors
- Designing and constructing an electric circuit to perform a simple function
- Analysing real or simulated circuits to identify faults and suggesting appropriate changes
- Comparing the efficiency of various electrical devices and suggesting ways of improving efficiency
- Measuring magnetic field strength by using simple current balance, search coil and Hall probe
- Performing demonstrations to show the relative directions of motion, force and field in electromagnetic devices
- Disassembling loudspeakers to determine the functions of individual components
- Investigating the magnetic fields around electric currents (e.g. around a long straight wire,

at the centre of a coil, inside and around a slinky solenoid and inside a solenoid)

- Constructing electric motor kits and generator kits
- Measuring the transformation of voltages under step-up or step-down transformers
- Estimating the e/m ratio by measuring the radius of curvature in a magnetic field of known strength
- Planning and selecting appropriate equipment or resources to demonstrate the generation of an alternating current
- Using computer simulations to observe and investigate the electric field and magnetic field
- Using dimension analysis to check the results of mathematical solutions
- Identifying hazardous situations and safety precautions in everyday uses of electrical appliances
- Investigating the need for and the functioning of circuit breakers in household circuits
- Reading articles on the possible hazardous effects on residents living near high voltage transmission cables
- Searching for information on the uses of resistors in common appliances (e.g. volume control, light dimmer switch)

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. 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 illustrated in the numerous inventions related to electricity
- to be aware of the importance of technological utilities such as the use of electricity, to 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 sustainable development of humankind
- to be aware of the danger of electric shocks and the fire risk associated with improper use of electricity, and develop good habits in using domestic electricity

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the effects on health of living near high-power transmission cables
- the potential hazards of the mains supply versus the convenience of "plug-in" energy and automation it offers to society
- the environmental implications and recent developments of electric vehicles as an alternative to traditional fossil-fuel vehicles; and the role of the government on such issues
- the views of some environmentalists on the necessity to return to a more primitive or natural lifestyle with minimum reliance on technology

V Radioactivity and Nuclear Energy (16 hours)

Overview

In this topic, nuclear processes are examined. Ionizing radiation is very useful in industrial and medical fields but at the same time is hazardous to us. Nuclear radiation comes from natural and artificial sources. It is essential for students to understand the origin of radioactivity, the nature and the properties of radiation. Students should also learn simple methods to detect radiation and identify major sources of background radiation in our natural environment. Simple numerical problems involving half-lives are performed in order to understand the long-term effects of some radioactive sources. The potential hazards of ionizing radiation are 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 by a symbolic notation. Students learn the concepts of isotopes. They are also introduced to fission and fusion, nature's most powerful energy sources.

Students should learn:	Students should be able to:
a. Radiation and Radioactivity	
X-rays	• realise X-rays as ionizing electromagnetic radiations of short wavelengths with high penetrating power • realise the emission of X-rays when fast electrons hit a heavy metal target • discuss the uses of X-rays
α, β and γ radiations	• describe the origin and nature of α, β and γ radiations • compare α, β and γ radiations in terms of their penetrating power, ranges, ionizing power, behaviour in electric field and magnetic field, and cloud chamber tracks
radioactive decay	• realise the occurrence of radioactive decay in unstable nuclides • examine the random nature of radioactive decay

Students should learn:	Students should be able to:
	• state the proportional relationship between the activity of a sample and the number of undecayed nuclei • define half-life as the period of time over which the number of radioactive nuclei decreases by a factor of one-half • determine the half-life of a radioisotope from its decay graph or from numerical data • realise the existence of background radiation • solve problems involving radioactive decay • <u>represent the number of undecayed nuclei by the exponential law of decay $N = N_o e^{-kt}$</u> • <u>apply the exponential law of decay $N = N_o e^{-kt}$ to solve problems</u> • <u>relate the decay constant and the half-life</u>
detection of radiation	• detect radiation with a photographic film and GM counter • detect radiation in terms of count rate using a GM counter
radiation safety	• represent radiation equivalent dose using the unit sievert (Sv) • discuss potential hazards of ionizing radiation and the ways to minimise the radiation dose absorbed • suggest safety precautions in handling radioactive sources

b. Atomic model

atomic structure	• describe the structure of an atom • define atomic number as the number of protons in the nucleus and mass number as the sum of the number of protons and neutrons in the nucleus of an atom • use symbolic notations to represent nuclides
isotopes and radioactive transmutation	• define isotope • realise the existence of radioactive isotopes in some elements • discuss uses of radioactive isotopes • represent radioactive transmutations in α, β and γ decays using equations

Students should learn:	Students should be able to:
c. Nuclear energy	
nuclear fission and fusion	• realise the release of energy in nuclear fission and fusion • realise nuclear chain reaction • realise nuclear fusion as the source of solar energy
<u>mass-energy relationship</u>	• <u>state mass-energy relationship $\Delta E = \Delta m\, c^2$</u> • <u>use atomic mass unit as a unit of energy</u> • <u>determine the energy release in nuclear reactions</u> • <u>apply $\Delta E = \Delta m\, c^2$ to solve problems</u>

(Note: The underlined text represents the extension component)

Suggested Learning and Teaching Activities

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 background radiation. Fire alarms making use of weak sources may also be used in student experiments under teachers' 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 background radiation.

Possible learning activities that students may engage in are suggested below for reference:

- Measuring background radiation by using a GM counter
- Showing the activity of a sample to be proportional to the remaining number of unstable nuclides by using simulation or decay analogy with dice
- Demonstrating the random variation of count rate by using a GM counter and a source
- Identifying sources of natural radiations and investigating why exposure to natural radiation is increased for airline crews and passengers
- Determining the factors leading to an increase in the concentration of radon in high-rise buildings

- Reading the specification for commercial products containing radiation such as smoke detectors
- Assessing the risks and benefits of using nuclear radiations in medical diagnosis
- Suggesting ways of disposing of radioactive wastes
- Estimating the half-life from a graph of activity plotted against time
- Searching for information on the use of radioactive dating, radioactive tracers, food irradiation and product sterilisation
- Searching for information on the ethics of using nuclear weapons
- Comparing the relative costs and benefits from the use of nuclear reactors with other methods of producing electrical power
- Searching for information on nuclear accidents and reporting a case study on them

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. 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 sources when 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 view in society on controversial issues and appreciate the need to respect others' points of view even when disagreeing; and to adopt a scientific attitude when facing controversial issues, such as the use of nuclear energy

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the use of nuclear power; the complex nature of the effects caused by developments in science and technology in our society
- the moral issue of using various mass destruction weapons in war
- 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 development of nuclear power
- the stocking and testing of nuclear weapons
- the use of fission reactors and the related problems such as disposal of radioactive wastes and leakage of radiation

2.3.2 Elective part (Total 50 hours, any 2 out of 4)

VI Astronomy and Space Science (25 hours)

Overview

Astronomy is the earliest science to emerge in history. The methods of measurement and the ways of thinking developed by early astronomers laid the foundation of scientific methods which influenced the development of science for centuries. The quest for a perfect model of the universe in the Renaissance eventually led to the discovery of Newton's law of universal gravitation and the laws of motion. This had a profound influence on the subsequent rapid development in physics. Using physical laws in mathematical form to predict natural phenomena, and verifying these predictions with careful observation and experimentation, as Newton and other scientists did some three hundred years ago, has become the paradigm of modern physics research. Physics has become the cornerstone of modern astronomy, revolutionising our concepts of the universe and the existence of humankind. Modern developments in space science, such as the launch of spacecraft and artificial satellites, still rely on Newtonian physics. In this topic, students have an opportunity to learn principles and scientific methods underpinning physics, and to appreciate the interplay between physics and astronomy in history, through studying various phenomena in astronomy and knowledge in space science.

Students are first given a brief introduction to the phenomena of the universe as seen in different scales of space. They are also encouraged to perform simple astronomical observations and measurements. Through these processes, they can acquire experimental skills, and become more familiar with the concept of tolerance in measurement. A brief historic review of geocentric model and heliocentric model of the universe serves to stimulate students to think critically about how scientific hypotheses were built on the basis of observation.

Kepler's third law and Newton's law of gravitation are introduced with examples of astronomy. Kepler's third law for circular orbits is derived from the law of gravitation and concepts of uniform circular motion, including centripetal acceleration. Besides the motion of planets, moons and satellites, latest astronomical discoveries can also serve as examples to illustrate the applications of these laws.

The concepts of mass and weight are applied. Feeling weightlessness in a spacecraft orbiting the Earth is explained in terms of the fact that acceleration under gravity is independent of mass.

The expression for gravitational potential energy can be obtained from the law of gravitation and work-energy theorem. Motions of artificial satellites are explained by the conservation of mechanical energy in their orbits. The meaning of escape velocity, together with its implications for the launching of a rocket, are introduced.

In the last part of this topic, students are exposed to astronomical discoveries, including the basic properties and classification of stars and the expansion of the universe. As only a simple, heuristic and qualitative understanding of these topics is expected, students are encouraged to learn actively by reading popular science articles and astronomical news – which promotes self-directed learning. Also, oral or written presentation of what they have learned may serve to improve their communication skills.

Students should learn:	Students should be able to:
a. The universe as seen in different scales	
structure of the universe	• use the "Powers of Ten" approach to describe the basic features and hierarchy of celestial bodies such as satellite, planet, star, star cluster, nebula, galaxy and cluster of galaxies, as seen in different spatial scales • define the basic terminologies such as light year and astronomical unit for describing the spatial scale
b. Astronomy through history	
models of planetary motion	• compare the heliocentric model with the geocentric model in explaining the motion of planets on the celestial sphere • describe Galileo's astronomical discoveries and discuss their implications • describe planetary motion using Kepler's laws

Students should learn:	Students should be able to:
c. Orbital motions under gravity	
Newton's law of gravitation	• apply Newton's law of gravitation $F = \frac{GMm}{r^2}$ to explain the motion of celestial bodies in circular orbits • derive Kepler's third law $T^2 \propto r^3$ for circular orbits from Newton's law of gravitation • state Kepler's third law for elliptical orbits $T^2 = \frac{4\pi^2 a^3}{GM}$ • apply Kepler's third law to solve problems involving circular and elliptical orbits
weightlessness	• explain apparent weightlessness in an orbiting spacecraft as a result of acceleration due to gravity being independent of mass
conservation of energy	• interpret the meaning of gravitational potential energy and its expression $U = -\frac{GMm}{r}$ • apply conservation of mechanical energy to solve problems involving the motion of celestial bodies or spacecraft • determine the escape velocity on a celestial body
d. Stars and the universe	
stellar luminosity and classification	• determine the distance of a celestial body using the method of parallax • use parsec (pc) as a unit of distance • realise magnitude as a measure of brightness of celestial bodies • distinguish between apparent magnitude and absolute magnitude • describe the effect of surface temperature on the colour and luminosity of a star using blackbody radiation curves • realise the existence of spectral lines in the spectra of stars • state major spectral classes: O B A F G K M and relate them to the surface temperature of stars

Students should learn:	Students should be able to:
	• state Stefan's law and apply it to derive the luminosity $L = 4\pi R^2 \sigma T^4$ for a spherical blackbody • represent information of classification for stars on the Hertzsprung-Russell (H-R) diagram according to their luminosities and surface temperatures • use H-R diagram and Stefan's law to estimate the relative sizes of stars
Doppler effect	• realise the Doppler effect and apply $\frac{\Delta\lambda}{\lambda_o} \approx \frac{v_r}{c}$ to determine the radial velocity of celestial bodies • use the radial velocity curve to determine the orbital radius, speed, and period of a small celestial body in circular orbital motion around a massive body as seen along the orbital plane • relate the rotation curve of stars around galaxies to the existence of dark matter • relate the red shift to the expansion of the universe

Suggested Learning and Teaching Activities

Students should develop basic skills in astronomical observation. Observation can capture students' imagination and enhance their interest in understanding the mystery of the universe. It also serves to develop their practical and scientific investigation skills. Students may use the naked eye to observe the apparent motion of celestial bodies in the sky, and use telescopes/binoculars to study the surface features of the Moon, planets and deep sky objects. Simple application of imaging devices such as a digital camera, webcam or charge-coupled device (CCD) is useful. Project-based investigation may also enhance students' involvement and interest. Space museums, universities and many local organisations have equipment and expertise on amateur astronomical observation, and welcome school visits and provide training for enthusiastic teachers.

Data handling skills such as converting radial velocity data into information on orbital motion is important. Due to the limitations of equipment, time, weather condition, and light pollution, however, it is quite difficult for students to obtain useful observation data for analysis. Animation may be used to complement this and to strengthen their understanding of the analytical content, and train their data- acquisition and handling skills. Standard animation tools, and a huge source of photos and videos are available in the NASA website. Software such as Motion Video Analysis may help students to use these resources to perform useful analysis. Connection of the analysed results with curriculum content and modern astronomical discoveries should be emphasised. This will help students to appreciate the importance of the physics principles they learn, and to realise that physics is an ever-growing subject with modern discoveries often emerging from the solid foundation laid previously.

Apart from the acquisition of practical and analytical skills, students may take the learning of advanced topics and new astronomical discoveries as a valuable opportunity to broaden their perspectives on modern science. They should not aim at a comprehensive understanding of these topics, but rather try to gain a simple, heuristic and qualitative glimpse of the wonders of the universe, as well as to appreciate the effort that scientists have made in these important discoveries. A huge number of astronomy education resources/articles is available on the Web. Students may develop the ability to learn independently through studying these materials, and polish their communication skills in sharing what they have learned with their classmates.

Possible learning activities that students may engage in are suggested below for reference:

- Observation of astronomical phenomena
  - Observing stars with the naked eye, and recognising the constellations and the apparent motion of celestial bodies in the sky
  - Observing meteor showers with the naked eye
  - Observing the surface of the Moon with a small telescope
  - Observing a lunar eclipse with a small telescope
  - Observing the features of major planets with a small telescope, like the belts and satellites of Jupiter, the phases of Venus, the polar caps of Mars, and the ring of Saturn
  - Observing special astronomical events such as the opposition of Mars, and the transit of Venus over the Sun with a small telescope
  - Observing bright comets with a small telescope
  - Observing binary stars and variable stars with a small telescope
  - Observing deep sky objects with a small telescope
  - Observing features of the Sun (e.g. sunspots and granules) and solar eclipse by projection
  - Recording the position and/or features of the above objects with a digital camera, a webcam or an astronomical CCD

- Possible learning activities
  - Constructing a sundial to make time measurement
  - Using a transparent plastic bowl to trace the path of daily motion of the Sun on the celestial sphere. Students can examine the paths in different seasons to understand how the altitudes of the Sun and the duration of sunshine vary throughout the year. (Reference: http://www.ied.edu.hk/apfslt/issue_2/si/article4/a4_1.htm)
  - Recording the position of Galilean satellites of Jupiter. Students may use the size of Jupiter as the reference length to estimate the period and orbital radius of the satellites. To avoid technical difficulties in observation, students may use the Solar System Simulator provided by NASA (http://space.jpl.nasa.gov/) and Motion Video Analysis Software (http://www.hk_phy.org/mvas) to perform a virtual analysis of the motion of satellites. They can also verify Kepler's third law in this case. (Reference: http://www.hk-phy.org/astro/tcs.zip)
  - Recording the position of planets/asteroids in the sky by using a digital camera over a few months. Students may use a star map to estimate the coordinates of the planets/ asteroids and use standard astronomical software to analyse the orbit of the planet.
  - Mapping of sunspots. Students may observe the projected image of the Sun and map the sunspots in a period of time. From this they can understand the rotation of the Sun and the evolution of sunspots. Recording the relative sunspot number over a period of time may also reveal the change in solar activity.
  - Studying the physics of Shenzhou manned spacecraft. The historic journey of Shenzhou involves many interesting physics phenomena that secondary school students can understand – for example, the thrust and acceleration of the rocket during its launch, the orbital motion around the Earth, the weightless condition in the spacecraft, the deceleration and return of the returning capsule, the effect of air resistance on the returning capsule, and communication problems when returning to the atmosphere. Analysis of spacecraft data provides a lively illustration of physics principles. Motion video analysis may also be useful in studying the launching motion.
  - Studying orbital data of artificial satellites provides an interesting illustration of Newtonian mechanics. Students may check the satellite pass-over time to actually observe the satellite in the evening sky.
  - Using a spectrometer and suitable filter to observe the spectrum of the Sun. Some prominent spectral absorption lines can be observed without much difficulty.
  - Studying radial velocity curves in celestial systems like stars with extrasolar planets, black holes in binaries, exposes students to the latest advances in astronomy. Based on the information extracted from the curves, students can use Kepler's third law to deduce the mass and orbital radius of the unknown companion in binary systems, and recognise the important implications of these discoveries for the existence of exotic celestial bodies and extraterrestrial life.
  - Studying articles about the latest astronomy discoveries can promote students' interest in modern science and strengthen their ability to learn independently. Oral or

written presentation in class is encouraged.
  - Visiting the Hong Kong Space Museum. Students may be divided into groups, with each group being responsible for gathering information on a particular astronomy topic in the exhibition hall of the museum. Each group can give a short presentation in class to share their learning experience.
- Contacting local organisations, observatories and museums
  - Hong Kong Space Museum (http://hk.space.museum)
  - Ho Koon NEAC (http://www.hokoon.edu.hk)
  - TNL Centre, The Chinese University of Hong Kong (http://www.cuhk.edu.hk/ccc/tnlcenter)
  - Sky Observers' Association (Hong Kong) (http://www.skyobserver.org)
  - Hong Kong Astronomical Society (http://www.hkas.org.hk/links/index.php)
  - Space Observers Hong Kong (http://www.sohk.org.hk)
- Using educational websites that provide useful resources for activities
  - Astronomy picture of the day (http://antwrp.gsfc.nasa.gov/apod/astropix.html)
  - NASA homepage (http://www.nasa.gov/home)
  - The Hubble Space News Center (http://hubblesite.org/newscenter)
  - Chandra X-ray Observatory (http://www.nasa.gov/centers/marshall/news/chandra)
  - Jet Propulsion Laboratory (http://www.jpl.nasa.gov/index.cfm)
  - NASA Earth Observatory (http://earthobservatory.nasa.gov)
  - China National Space Administration (http://www.cnsa.gov.cn)
  - National Astronomical Observatories, Chinese Academy of Sciences (http://www.bao.ac.cn)

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to appreciate the wonders of deep space and understand the position of humankind in the universe
- to appreciate astronomy as a science which is concerned with vast space and time, and the ultimate quest for the beginning of the universe and life
- to appreciate how careful observation, experimentation and analysis often lead to major discoveries in science that revolutionise our concepts of nature
- to appreciate physics as an ever growing subject in which new discoveries are often made on the solid foundation that was laid previously
- to appreciate the ability of famous scientists in history and their profound contribution towards our understanding of the universe and the existence of humankind
- to accept uncertainty in the description and explanation of physical phenomena

- to accept the uncertainty in measurement and observation but still be able to draw meaningful conclusions from available data and information
- to be able to get a simple and heuristic glimpse of modern advances in science, even though a comprehensive understanding of these advanced topics is beyond the ability of ordinary people
- to recognise the importance of lifelong learning in our rapidly changing knowledge-based society and be committed to self-directed learning
- to appreciate the roles of science and technology in the exploration of space and to appreciate the efforts of humankind in the quest for understanding nature
- to become aware of daily phenomena and their scientific explanations

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- studies in astronomy which have stimulated the development of modern science and eventually changed our ways of living
- the interplay between technological development, the advance of modern science and our lives
- the effects of astronomical phenomena on our lives (e.g. solar activity maximum affects communication and power supply on Earth)
- the effects of light pollution on astronomical observations, the environment and the lifestyle
- disasters that may come from outer space and our reactions to them (e.g. a big meteor impact causing massive destruction to life on Earth)
- the applications of modern technologies in space science, including artificial satellites and spacecraft
- the need to rethink some of Earth's environmental problems as a result of exploration of planets (e.g. the runaway greenhouse effect of Venus may be compared with global warming on Earth)
- the implications of the advances in space technology and their impact on society (e.g. Shenzhou manned spacecraft)

VII Atomic World (25 hours)

Overview

The nature of the smallest particles making up all matter has been a topic of vigorous debate among scientists, from ancient times through the exciting years in the first few decades of the 20th century to the present. Classical physics deals mainly with particles and waves, as two distinct entities. Substances are made of very tiny particles. Waves, such as those encountered in visible light, sound and heat radiations, behave very differently from particles. At the end of the 19th century, particles and waves were thought to be very different and could not be associated with each other.

When scientists looked more closely at the nature of substances, contradictory phenomena that confused scientists began to appear. Classical concepts in Mechanics and Electromagnetism cannot explain the phenomena observed in atoms, or even the very existence of atoms. Studies on the structure of an atom and the nature of light and electrons revealed that light, the wave nature of which is well known, shows particle properties, and electrons, the particle nature of which is well known, show wave properties.

In this elective topic, students learn about the development of the atomic model, the Bohr's atomic model of hydrogen, energy levels of atoms, the characteristics of line spectra, the photo-electric effect, the particle behaviour of light and the wave nature of electrons, i.e. the wave-particle duality. Through the learning of these physical concepts and phenomena, students are introduced to the quantum view of our microscopic world and become aware of the difference between classical and modern views of our physical world. Students are also expected to appreciate the evidence-based, developmental and falsifiable nature of science.

Advances in modern physics have led to many applications and rapid development in materials science in recent years. This elective includes a brief introduction to nanotechnology, with a discussion on the advantages and use of transmission electron microscopes (TEM) and scanning tunnelling microscopes (STM), as well as some potential applications of nano structures.

Nanotechnologies have been around for hundreds of years, although the underlying physics was not known until the 20th century. For example, nano-sized particles of gold and silver have been used as coloured pigments in stained glass since the 10th century. With better understanding of the basic principles, more applications have been found in recent years. These applications include the potential use of nano wires and nano tubes as building materials and as key components in electronics and display. Nano particles are used in suntan lotions and cosmetics, to absorb and reflect ultra-violet rays. Tiny particles of titanium dioxide, for example, can be layered onto glass to make self-cleaning windows.

As in any newly developed area, very little is known, for example, about the potential effects of free nano particles and nano tubes on the environment. They may cause hazards to our health and might lead to health concerns. Students are, therefore, expected to be aware of the potential hazards, and issues of risk and safety to our life and society in using nanotechnologies.

In studying this elective topic, students are expected to have basic knowledge about force, motion, and waves. Some basic concepts of covalent bonds of electrons would be helpful in understanding the structures and special properties of nano materials. Knowledge of electromagnetic forces, electromagnetic induction and electromagnetic spectrum is also required.

Students should learn:	Students should be able to:
a. Rutherford's atomic model	
the structure of atom	• describe Rutherford's construction of an atomic model consisting of a nucleus and electrons • state the limitations of Rutherford's atomic model in accounting for the motion of electrons around the nucleus and line spectra • realise the importance of scattering experiments in the discovery of the structure of atoms and the impact on the searching for new particles
b. Photoelectric effect	
evidence for light quanta	• describe photoelectric effect experiment and its results • state the limitations of the wave model of light in explaining the photoelectric effect

Students should learn:	Students should be able to:
Einstein's interpretation of photoelectric effect and photoelectric equation	• state photon energy $E = hf$ • describe how the intensity of the incident light of a given frequency is related to the number of photons • explain photoelectric effect using Einstein's photoelectric equation $hf - \phi = \frac{1}{2} m_e v_{max}{}^2$ • realise the photoelectric effect as the evidence of particle nature of light • apply $E = hf$ and Einstein's photoelectric equation to solve problems
c. Bohr's atomic model of hydrogen	
line spectra	• describe the special features of line spectra of hydrogen atoms and other monatomic gases • explain spectral lines in terms of difference in energies • realise that the energy of a hydrogen atom can only take on certain values • realise line spectra as evidence of energy levels of atoms
Bohr's model of hydrogen atom	• state the postulates that define Bohr's model of hydrogen atom • distinguish between the "quantum" and "classical" aspects in the postulates of Bohr's atomic model of hydrogen • realise the postulate $m_e vr = \frac{nh}{2\pi}$ as the quantization of angular momentum of an electron around a hydrogen nucleus where n=1,2,3... is the quantum number labelling the n^{th} Bohr orbit of the electron • realise the equation for the energy of an electron in a hydrogen atom as E_{tot} $\left(= -\frac{1}{n^2}\left\{\frac{m_e e^4}{8h^2\varepsilon_o^2}\right\} \right) = -\frac{13.6}{n^2}$ eV • use electron-volt (eV) as a unit of energy • distinguish ionization and excitation energies • apply $E_{tot} = -\frac{13.6\,\text{eV}}{n^2}$ to solve problems

Students should learn:	Students should be able to:
the interpretation of line spectra	• derive, by using Bohr's equation of electron energy and $E=hf$, the expression $\frac{1}{\lambda_{a\to b}}=\frac{13.6\text{ eV}}{hc}\left\{\frac{1}{b^2}-\frac{1}{a^2}\right\}$ for the wavelength of photon emitted or absorbed when an electron undergoes a transition from one energy level to another • interpret line spectra by the use of Bohr's equation of electron energy • apply $E=hf$ and $\frac{1}{\lambda_{a\to b}}=\frac{13.6\text{ eV}}{hc}\left\{\frac{1}{b^2}-\frac{1}{a^2}\right\}$ to solve problems
d. Particles or Waves	• realise the wave-particle duality of electrons and light • describe evidences of electrons and light exhibiting both wave and particle properties • relate the wave and particle properties of electrons using the de Broglie formula $\lambda=\frac{h}{p}$ • apply $\lambda=\frac{h}{p}$ to solve problems
e. Probing into nano scale	
physical properties of materials in nano scale	• understand that nano means 10^{-9} • realise that materials in nano scale can exist in various forms, such as nano wires, nano tubes and nano particles • realise that materials often exhibit different physical properties when their sizes are reduced to nano scale
seeing at nano scale	• describe the limitations of optical microscope in seeing substances of small scale • describe how a transmission electron microscope (TEM) works • draw the analogy between the use of electric and magnetic fields in TEMs and lenses in optical microscopes • estimate the anode voltage needed in a TEM to accelerate electrons achieving wavelengths of the order of atomic size • explain the advantage of high resolution of TEM using

Students should learn:	Students should be able to:
	Rayleigh criterion for minimum resolvable detail, $\theta \approx \frac{1.22\lambda}{d}$
	• describe how a scanning tunnelling microscope (STM) works in seeing nano particles (principles of the tunnelling effect are *not* required)
recent development in nanotechnology	• describe recent developments and applications of nanotechnology in various areas related to daily life • discuss potential hazards, issues of risks and safety concerns for our lives and society in using nanotechnology

Suggested Learning and Teaching Activities

Students might follow the history of the discovery of atom when learning this elective topic. They should develop knowledge of the structure of atoms, the energy levels of electrons and quantized energy of light. The work of various physicists such as Rutherford, Bohr and Einstein, in the search for the nature of atoms and light should be recognised. Students should become aware of the importance of cooperation among scientists in investigations and discoveries related to nature. They should understand the limitations of Rutherford's atomic model in accounting for the motion of electrons around the nucleus and line spectra in the view of classical mechanics. They should be aware of the importance of the use of scattering experiment with energetic particles in the search of atomic structure. Such experiments had led to the discovery of many new particles in the 20th century, including protons and neutrons, and the internal structure of nucleons, i.e., the discovery of quarks. With the discovery of the photoelectric effect and Einstein's explanation, the particle nature of light became clear. Students should understand the details of the photoelectric effect and electron diffraction through experiments or computing animations. Bohr's postulates on the discrete energy level of an electron in an atom should be treated as a first step to revealing the quantum nature of matter. The emission and absorption line spectra observed from monatomic gases are used as evidence for the energy levels of electrons. Students should also recognise how the concept of wave-particle duality of electrons and light can successfully explain the phenomena observed.

After studying this elective topic, students should also understand the development of nanotechnology and its contribution to daily life. They should recognise that there are common forms of substances in nano scale, viz. nano particles, fullerenes, nano tubes and nano wires. Special physical properties are found, depending on the different structures of the nano substance. Carbon atom is one of the appropriate substances used to illustrate the various physical properties due to the different forms of its structure. Students should appreciate and have a basic understanding of the use of advanced tools, such as the transmission electron microscope (TEM) and scanning tunnelling microscope (STM) to see substances at nano scale. The introduction of the scanning tunnelling microscope will help them to recognise that probability is in fact a governance factor in the atomic world, in contrast to the determinate aspect of classical mechanics.

Students are encouraged to carry out project-type investigations into the development of nanoscience and nanotechnology, and into their impact on society and daily life. Through inquiry into social issues, students will become aware of the ethical and potential concerns (health and otherwise) of the use of nanotechnology. They will also appreciate the contributions of technological advancement, its influence on our daily life and its limitations.

Possible learning activities that students may engage in are suggested below for reference:

- Performing experiments on Rutherford's atomic model:
  - Using α scattering analogue apparatus for studying Rutherford scattering by means of a gravitational analogue of inverse square law
- Performing experiments on the photoelectric effect:
  - Using photocell (magnesium ribbon) to find out the threshold frequency
  - Using photocell to measure the stopping potential of monochromatic light
  - Using photocell to measure the energy of photoelectrons induced by different colours of light
  - Investigating the relationships among light intensity and the energy of photoelectrons
  - Inferring the relationships among threshold frequency, stopping voltage and the kinetic energy of electron
- Performing the Franck-Hertz experiment to demonstrate the discreteness of atomic energy levels
- Performing experiments involving observations of absorption and emission spectra.
- Using diagrams, photographs, computing animations and programmes to enhance their understanding of:
  - Rutherford's atomic model
  - Bohr's model
  - emission spectrum
  - absorption spectrum
  - Franck-Hertz experiment
  - photoelectric effect

  - electron diffraction
  - limit of resolution
- Illustrating the basic properties of the covalent bond of electrons by using
  - balls and sticks to build models
  - computing animations and programmes to display 2-D or 3-D images of simple covalent molecules
- Performing experiments to show how the diffraction patterns of two monochromatic point sources demonstrate the limit of resolution
- Performing estimations of the diffraction-limited vision of the human eye, for example, with an iris of diameter of 5 mm and a wavelength of 500 nm, by using the Rayleigh criterion
- Performing experiments to demonstrate different physical properties of nano materials (e.g. the Lotus effect)
- Investigating the application of the principles of nanoscience in commercial products by the use of various properties of nano materials (e.g. permeability to gas, water-repellence and transparency)
- Challenging their preconceived ideas on atomic models, and the nature of electrons and light
- Learning about scientists (e.g. Phillipp Lenard, Max Planck, Albert Einstein, Ernest Rutherford, Niels Bohr and de Broglie) and in particular their contributions to the development of atomic physics
- Increasing their awareness of the importance of collaboration among scientists in investigating nature

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. 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 appreciate the efforts made by scientists to discover the nature of light and the structure of an atom
- to appreciate the contributions of Rutherford, Bohr, Planck and Einstein to revolutionising the scientific thinking of their times
- to appreciate that important scientific theories, such as Rutherford’s atomic model and photoelectric effect, can ultimately have a huge impact on technology and society
- to be open-minded in evaluating potential applications of the theory of fundamental particles and nanotechnology
- to recognise the falsifiable nature of scientific theory and the importance of evidence in

supporting scientific findings

- to recognise the importance of lifelong learning in our future rapidly changing knowledge-based society and commit to self-directed learning

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the applications of nano-sized wires and tubes in other disciplines (e.g. Electronics, Optics, Medicine, Computing and Building Engineering)
- the influence of nanotechnology on our health and lives
- concerns about the potential risks to the environment of using nanotechnology
- the roles of nanotechnology in the world's economic growth
- the ethical and social implications caused by the use of nanotechnology in areas such as the military, medicine, and personal security and safety of society

VIII Energy and Use of Energy (25 hours)

Overview

The ability of human beings to use various forms of energy is one of the greatest developments in human history. Electrical energy brings cities to life. Modern transportation powered by energy links peoples together. Modern society is geared to using electricity as a main energy source. There are many reasons why electricity is the most common energy source used at home and in the office. This elective topic begins by reviewing domestic appliances for lighting, cooking and air-conditioning. These appliances show how physics principles are used to make our homes better and more comfortable places to live in. Students investigate the total amount of energy transferred when these appliances are in operation. They also learn how to calculate the cost from power rating of the appliances. The idea of energy changes being associated with energy transfer is raised, and students identify the energy changes associated with a range of appliances. This leads into the introduction of the Energy Efficiency Labelling Scheme informing the public to choose energy-efficient household appliances for saving energy. Building and transportation provide situations for students to study the factors affecting energy performance in real contexts. Building materials provide the starting point for discussion of the thermal properties of different materials to transfer energy; and this leads to consideration of a building design to minimise energy use and provide an appropriate internal environment without sacrificing its quality. Through the use of electric motors as energy converters in vehicles, students study the efficiency of electric motors compared to internal combustion engines, in the attempt to reduce air pollution.

There are many energy sources used as fuel that can be converted into electricity. The current fuels used for generating electricity in Hong Kong include coal, petroleum, natural gas, nuclear fuel and pump storage. Students compare the efficiency of different fuels and different ways of using the same fuel. Through a consideration of the design features of a solar cooker, students investigate conduction, convection and radiation as means of transferring energy from nature. Different sources of energy have different environmental effects on society. When fossil fuels burn, a large amount of pollutants are discharged into the air. The pollutants cause atmospheric pollution, reduce air quality and contribute to the greenhouse effect which may warm and damage the Earth. Whereas nuclear power stations are very efficient, the disposal of dangerous radioactive waste materials continues to be a problem. The growing concern about the environmental impact of energy polluting the environment has made environmentally friendly and alternative energy sources worth considering. In this connection, emphasis is placed on the energy conservation principle, to encourage efficient energy usage in order to maintain and improve the quality of the environment. Energy efficiency can be described simply using an input-output model. For example, a solar cell can be understood generally as a transducer that has the solar radiation as input and a useful form of electrical energy as the output. Despite the fact that Hong Kong has no indigenous energy sources, solar cells and wind power are introduced as local contextual examples to illustrate the concept of renewable energy sources. This elective topic increases students' understanding of the application of physics, the uses of different energy sources and the implications of energy efficiency to the environment.

Students should learn:	Students should be able to:
a. Electricity at home	
energy consuming appliances at home	• state electricity as the main source for domestic energy • describe the energy conversion involved in electrical appliances • define end-use energy efficiency in terms of the ratio of the amount of useful energy output to energy input
lighting	• state the different types of lighting used at home • describe how incandescent lamps, gas discharge lamps and light emitting diodes (LED) work and interpret light emission in terms of energy change in atomic level • discuss cost effectiveness of incandescent lamps, gas discharge lamps and light emitting diodes • realise that the eye response depends on wavelengths • define luminous flux as the energy of light emitted per unit time by a light source • use lumen as a unit of luminous flux • define illuminance as luminous flux falling on unit area of a surface • use lux as a unit of illuminance • use inverse square law and Lambert's cosine law to solve problems involving illuminance • define efficacy of electric lights as a ratio of luminous flux (lm) to electrical power input (W) and solve related problems
cooking without fire	• describe how electric hotplates, induction cookers and microwave ovens work in heat generation

Students should learn:	Students should be able to:
	• use the power rating of cookers to determine running cost • solve problems involving end-use energy efficiency of cookers • discuss the advantages and disadvantages of electric hotplates, induction cookers and microwave ovens
moving heat around	• describe how air-conditioner as a heat pump transfers heat against its natural direction of flow • interpret cooling capacity as the rate at which a cooling appliance is capable of removing heat from a room and use kilowatt (kW) as a unit for cooling capacity to solve related problems • define coefficient of performance COP as ratio of cooling capacity to electrical power input and solve related problems • discuss possible ways of using heat generated by central air-conditioning systems
Energy Efficiency Labelling Scheme	• discuss the uses of the Hong Kong Energy Efficiency Labelling Scheme (EELS) for energy-saving • solve problems involving EELS • suggest examples of energy-saving devices
b. Energy efficiency in building and transportation	
building materials used to improve the energy efficiency	• interpret $\frac{Q}{t} = \frac{\kappa}{d} A(T_{hot} - T_{cold})$ as the rate of energy transfer by conduction and discuss the heat loss in conduction • define thermal transmittance U-value of building materials as $u = \frac{\kappa}{d}$ and solve related problems • define the Overall Thermal Transfer Value (OTTV) as the average rate of heat gain per unit area into a building through the building envelope and solve related problems • discuss factors affecting the OTTV • discuss the use of solar control window film in a building • discuss the factors affecting the energy efficiency of buildings

Students should learn:	Students should be able to:
electric vehicles	• state the main components of the power system of electric vehicles • discuss the use of electric vehicles • state the main components of the power system of hybrid vehicles and compare their end-use energy efficiency to fossil-fuel vehicles • discuss the advantages of public transportation systems and give examples
c. Renewable and non-renewable energy sources	
renewable and non-renewable energy sources	• describe the characteristics of renewable and non-renewable energy sources and give examples • define solar constant as the total electromagnetic radiation energy radiated at normal incidence by the Sun per unit time per unit area at the mean distance between the Earth and the Sun measured outside the Earth's atmosphere • solve problems involving the solar constant[3] • derive maximum power by wind turbine as $P = \frac{1}{2}\eta\rho A v^3$, where η is the efficiency and solve problems • describe the energy conversion process for hydroelectric power and solve problems • define binding energy per nucleon in unit of eV and solve problems • relate the binding energy curve to nuclear fission and fusion • describe the principle of the fission reactor and state the roles of moderator, coolant and control rods • describe how a solar cell works
environmental impact of energy consumption	• discuss the impact of extraction, conversion, distribution and use of energy on the environment and society • discuss effect of greenhouse gases on global warming • analyse the consumption data for different fuel types in Hong Kong and their specific purposes

[3] *The content was revised in September 2009.*

Suggested Learning and Teaching Activities

This topic should provide learning experiences for students to understand the production, conversion, transmission and utilisation of energy. The design of learning experiences should seek to integrate content, skills and process, and values and attitudes through a meaningful pedagogy.

Students construct knowledge best when they can make use of daily-life contexts and technological issues. For example, the Building Integrated Photovoltaic (BIPV) Design for Hong Kong, the Wind Turbine Project in Lamma Island, and the Ducted Wind Turbine Project can be used to raise their awareness of renewable energy sources. Discussion questions and learning activities related to the range of available energy efficient technologies are used to motivate students to explore these, and hence discover by themselves the underlying energy efficiency principles. The knowledge, values and attitudes involved in being a smart energy consumer should also be central to this topic. Generic skills used for communication, critical thinking, creativity and problem-solving should be embedded in discussion leading to issues related to energy utilisation and conservation. Information, real data, themes, events and issues in Hong Kong that illustrate these key concepts should be provided to facilitate learning and teaching. Students are firstly engaged by an event or a question related to a concept, and then they participate in one or more activities to explore the concept. This exploration provides them with experiences from which they can develop their understanding. Where necessary, the teacher clarifies the concept and defines relevant vocabulary. Then the students elaborate and build on their understanding of the concept by applying it to new situations. Finally, the students complete activities and the teacher evaluates their understanding of the concept.

Possible learning activities that students may engage in are suggested below for reference:

- Performing an investigation to model the generation of electric current by conducting relative motion between a magnet and a coil
- Gathering and analysing information related to incandescent lamps (e.g. filament light bulb, halogen lamp), gas discharge lamps (e.g. linear or compact fluorescent lamp, high pressure mercury or sodium lamp, induction lamp) and light emitting diode (LED)
- Using a motor-generator kit to show students how electricity can be generated using mechanical energy
- Identifying and analysing different energy sources, discussing the advantages and disadvantages of each energy source, and coming to a consensus
- Analysing information about the effect of greenhouse gases on global warming
- Gathering and analysing information to identify how high tension cables are insulated

from power pylons, protected from lightning strikes and cleaned from dirt

- Performing an investigation to model the structure of a transformer to demonstrate how secondary voltage is produced and investigate the transformer action
- Gathering, processing and analysing information to identify some of the energy transfers and transformations involving the conversion of electrical energy into more useful forms in the home and industry
- Organising a class competition on solar cooker, wind power generation, or a solar car race
- Investigating variables in the use of solar energy for water heating, for cooking and for generating electricity
- Building a circuit to generate electricity by solar energy
- Designing an investigation to determine whether heat or light generates electricity in a solar cell
- Visiting local power plants and the nuclear power plant in Daya Bay
- Listening to invited speakers from the Electrical and Mechanical Services Department, Green Power, CLP Power Hong Kong Limited, Hong Kong Electric Company Limited, Towngas, MTR, KCR or the Environmental Protection Department to introduce up-to-date information on energy generation, transmission and consumption in society and alternative energy sources
- Gathering and analysing information on different forms of renewable and non-renewable energy sources, giving some examples of different energy sources (e.g. solar, tidal, water, wind, fossil and nuclear energy)
- Studying the impact of extraction, conversion, distribution and use of energy on the environment and society, and their suitability for different situations
- Discussing the accessibility of fossil and non-fossil fuel energy sources
- Gathering and analysing information on the interaction of energy sources with greenhouse gases: such as energy absorption, re-emission, radiation and dissipation by greenhouse gases
- Considering what can be done to make the generation and use of electricity for more sustainable use in Hong Kong
- Measuring the heat produced by a flashlight bulb and calculate the efficiency of the bulb
- Suggesting ways to control the transfer of solar energy into buildings
- Planning investigations to compare solar energy transfer through two different kinds of solar control window film
- Demonstrating an understanding of the applications of energy transfer and transformation
- Discussing energy usage at home and in the office to increase awareness of the need for energy economy
- Carrying out an energy audit on their own homes or schools – for example, measuring the amount of electrical energy used at home in a month by reading the electricity bill and estimating what proportion of this energy is used for lighting, for air-conditioning (or space heating), for heating water, for washing and cleaning, and for cooking
- Studying the Energy Efficiency Labelling Scheme (EELS) in Hong Kong and information contained in Energy Labels

- Writing about the proper use of domestic electrical appliances to reduce the cost of electricity and contribute to the worthwhile cause of saving energy
- Writing about home safety in relation to the use of electrical appliances
- Discussing "Life without electricity for a day"
- Discussing how the availability of electrical appliances has changed life in Hong Kong over the years
- Discussing family preparedness for periods of electrical outage
- Studying "disorderness" which implies an irreversible change that everything tends to become less organised and less orderly over time. Understanding that the overall effect of all energy transfer is to spread energy out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, convection and radiation, and the warming of our surroundings when burning fuels.
- Studying the Code of Practice on Overall Thermal Transfer Value (OTTV) in the website of the Buildings Department (http://www.bd.gov.hk/english/documents/code/e_ottv.htm) and discussing the effect of U-values on thermal conduction for different building materials
- Studying the Code of Practice for energy saving in the website of Electrical and Mechanical Services Department (http://www.emsd.gov.hk/emsd/eng/pee/eersb_pub.shtml) and discussing its impacts on the building services systems (i.e. mechanical and electrical systems)
- Gathering and comparing information related to end-use energy efficiency for air conditioners, lamps and cars.

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to be aware of the finite energy sources available to humans and the need to save electrical energy for a sustainable economy and environmental protection
- to be aware of the environmental implications of the use of different energy sources and to share the responsibility for sustainable development of Hong Kong
- to appreciate the efforts made by scientists to find alternative environmentally friendly energy sources
- to appreciate the efforts of humankind to protect the environment
- to be open-minded in evaluating the potential applications of new technologies for improving energy efficiency
- to appreciate energy-saving behaviour in daily life and to be committed to good practices for energy consumption

- to be aware of the impacts of electricity on Hong Kong over the years
- to be aware of the consumers' responsibility to know the energy efficiency of home appliances via energy labels
- to be aware of the importance of safety issues in using electrical appliances and committed to safe usage
- to appreciate that the important advances in scientific theory (such as semi-conductor theory and mass-energy conversion theory) can ultimately make a huge impact on technology and society
- to be aware of the importance of lifelong learning in our rapidly changing knowledge-based society and be committed to self-directed learning

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the trade-off between the applications of different energy sources and their environmental impact
- the safety problems associated with the storage and transportation of fuels
- restricting the use of private motor cars in order to reduce air pollutants
- the issue of the detrimental effects of electromagnetic fields emitted by high tension cables and power pylons
- the environmental implications and recent developments of electric vehicles as an alternative to traditional fossil-fuel vehicles, and the role of the government in such issues
- the environmental impact of the wind turbine on scenic natural surroundings
- the selection of sites for power plants as a matter for debate because such sites may alter coastal habitats

IX Medical Physics (25 hours)

Overview

This elective is concerned with the basic physics principles underlying human vision and hearing to make sense of the environment. It begins by considering the structures of the eye and its optical system for adjusting to different object distances. Defects of vision and the study of their corrections are introduced. Resolution is introduced to explain the fineness of detail discernible by the eye. The question of how colour vision is generated leads to the study of the rods and cones in the retina. Rods are responsible for vision in dim light while cones are responsible for the more acute vision experienced in ordinary daylight conditions. A brief look at the structure of the ear serves to introduce students to concepts of transferring energy using a transducer and how different frequencies of sound waves are discriminated in the inner ear.

Attention is then given to the applications of sound waves and visible light for seeing inside the body. A brief look at the work of ultrasound scanners and endoscopes serves to introduce students to pulse-echo and the total internal reflection of waves. Ionizing radiation, such as X-rays and gamma rays, is introduced to students as an alternative means of examining the anatomical structures and functions of a body for medical diagnosis. In hospitals and clinics around the world, literally hundreds of thousands of patients daily receive medical imaging tests in which X-rays, radionuclides, ultrasound and computed tomography (CT) are used. In virtually all these devices, physics has developed from our understanding of the electromagnetic spectrum, the radioactivity of specific nuclides and the wave properties of ultrasound beams. Such devices have enabled radiologists to see through the body without surgery. The medical uses of radioactive substances are introduced to students and the ways in which gamma radiation can be detected by gamma cameras to produce images for medical diagnosis are considered. It should be emphasised that the development of new imaging modalities is an evolutionary process. It may start with the discovery of a new physical phenomenon or a variation of an existing one. At all stages, expertise in physics is essential. There is considerable interest in medical physics in the field of radiation oncology, nuclear medicine and radiology, and some students will want to know more about such developments.

Students should learn:	Students should be able to:
a. Making sense of the eye and the ear	
physics of vision	• describe the function of light sensitive cells (rods and cones) of retina in vision • interpret spectral response of light sensitive cells using receptor absorption curves • apply resolving power $\theta \approx \frac{1.22\lambda}{d}$ to solve problems • describe the process of accommodation of the eye
defects of vision and their corrections	• define power of a lens as the reciprocal of the focal length of a lens • use dioptre as a unit of power of a lens • state the near point and far point of the eye • describe the defects of vision including short sight (myopia), long sight (hypermetropia) and old sight (presbyopia) and their corrections
physics of hearing	• describe the pressure amplification in the middle ear • realise the response of the inner ear to incoming sound waves • realise hearing perception of relative sound intensity levels and the need for a logarithmic scale to represent the levels • apply sound intensity level $L = 10\log_{10}(\frac{I}{I_o})$ dB to solve problems • interpret the curves of equal loudness • discuss the effects of noise on health of hearing
b. Medical imaging using non-ionizing radiation	
properties of ultrasound	• describe how a piezoelectric transducer works in generating and detecting an ultrasound pulse • define acoustic impedance $Z = \rho c$ and compare the acoustic impedances of various body tissues

Students should learn:	Students should be able to:
	• apply intensity reflection coefficient $\alpha = \frac{I_r}{I_o} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ to solve problems • realise the dependence of attenuation of ultrasound on the nature of the medium and the frequency
ultrasound scans	• realise A-scan and B-scan as range-measuring systems • describe how A-scan works • interpret the pulse display of A-scan • identify suitable frequency ranges of ultrasound for scanning based on penetration depth, resolution and body structures • describe how B-scan works • estimate the size of a body tissue in a B-scan image • discuss the advantages and limitations of ultrasound scans in diagnosis
fibre optic endoscopy	• describe the characteristics of an optical fibre • describe how a fibre optic endoscope works • describe how coherent bundle fibres form image • solve problems involving optical fibre • discuss the advantages and limitations of using endoscope in diagnosis
c. Medical imaging using ionizing radiation	
X-ray radiographic imaging	• apply $I = I_o e^{-\mu x}$ to determine the transmitted intensity of a X-ray beam after travelling through a certain thickness in a medium • relate the linear attenuation coefficient (μ) to half-value thickness • realise a radiographic image as a map of attenuation of X-ray beam after passing body tissues • explain the use of artificial contrast media such as barium meal in radiographic imaging

Students should learn:	Students should be able to:
	• discuss the advantages and disadvantages of radiographic imaging in diagnosis
CT scan	• describe how a computed tomography (CT) scanner works • realise a CT image as a map of attenuation coefficients of body tissues • realise the image reconstruction process of CT scanning • compare CT images with X-ray radiographic images
radionuclides for medical uses	• identify the characteristics of radionuclides such as technetium-99m used for diagnosis • define biological half-life as the time taken for half the materials to be removed from the body by biological processes and apply it to solve related problems • describe the use of radioisotopes as tracers for diagnosis • realise a radionuclide image obtained by a gamma camera as a map of radioisotopes distribution in a body • compare radionuclide planar images with X-ray radiographic images • compare effective dose in diagnostic medical procedures involving ionizing radiation • discuss the health risk and safety precautions for ionizing radiation

Suggested Learning and Teaching Activities

This topic focuses mainly on the applications of physics in medicine using non-ionizing radiation as well as ionizing radiation for medical diagnosis. The eye is used to model an optical device and the ear as a mechanical transducer. They enable human to react to change in the environment through nervous reactions. Historical perspectives on the discovery of X-rays and radioactivity can be introduced. For example, perhaps the earliest medical imaging experiment was the imaging by Rontgen of his wife's hand within weeks after he discovered X-rays. Ultrasound as a medical imaging modality is really an application of Sound Navigation and Ranging developed during the Second World War. Ultrasound scanners are used to view the foetus during pregnancy. The use of ionizing radiation in medicine may be said to stem from two discoveries at the end of the 19^{th} century: Roentgen's discovery of X-rays in 1895 and Becquerel's discovery of radioactivity in 1896. Both these discoveries had a major impact on how medicine is practised. X-rays have since been used for seeing through the body and for the treatment of cancer, with radionuclides also being used for both purposes. The use of X-rays to investigate the body has resulted in the development of the field of diagnostic radiology. The use of X-rays along with the treatment with the radiation emitted by radioactive decay for the treatment of malignant tumours resulted in the development of the field of radiation oncology or radiotherapy. After the Second World War, numerous artificially-produced radionuclides became available. As well as being used for the treatment of cancer, radionuclides were used to localise specific organs and diseases in the body. This resulted in the development of the field of nuclear medicine. With the development of digital computers and the advancement of image reconstruction algorithms, it became possible to reconstruct cross-sectional images of the body, resulting in the 1970s in computerised tomography. Such technological advances help students to appreciate the importance of physics, mathematics, engineering and computer science in the design of medical imaging devices.

Students should develop skills in searching for information from the World Wide Web. A great deal of up-to-date information and image data for educational purposes is available on the Web. For example, one can start by asking the students to explore the differences in images obtained from various scans, such as ultrasound, gamma camera and CT, in relation to the information content from the images. Also, the concepts of representing image in number can be introduced, and so manipulating those numbers which can modify the image. The combination of image visualisation and processes has had an enormous effect on extracting and representing image data. Resolution is a fundamental characteristic of all measuring devices. The resolution of any instrument is the smallest difference which is detectable. In this connection, students are encouraged to carry out comparisons to differentiate the appearance of specific images and realise the smallest size of things which can be distinguished by different medical imaging devices, so as to introduce the concepts related to spatial resolution. It is also interesting to note that the idea of resolution also applies to the grey levels in the digital images. A simple back projection algorithm can be used to simulate image reconstruction from projection data. To arouse their interest, students may be asked to discuss open questions such as: Is ultrasound scanning safe in pregnancy? How do you detect cancer? Are computers making doctors less important?

Students are also encouraged to extend their reading from textbooks to articles, popular science magazines and the Web. In particular, there are relevant collections of articles in the e-museum at the Nobel Foundation (http://nobelprize.org/) for student browsing. If students follow their own reading interests, they are likely to find many pages there that convey the joy these Nobel Laureates have in their work and the excitement of their ideas.

Possible learning activities that students may engage in are suggested below for reference:

- Reading articles and discussing the applications related to laser-assisted in-situ keratomileusis (LASIK) or other new technology for eye surgery
- Reading articles and discussing the applications related to electronic cochlear implant
- Observing images produced by ultrasound scans, endoscopes, X-rays, CT scans and gamma camera
- Demonstrating the principles of pulse-echo using ultrasound transmitters and receivers
- Solving problems and analysing information to calculate the acoustic impedance of a range of materials, including bone, muscle, soft tissue, fat, blood and air, and explaining the types of tissues that can be examined by ultrasound
- Using a pair of ultrasound transmitter and receiver to investigate the amplitude of echo from reflectors of different materials
- Observing an ultrasound image of body organs and gathering information
- Estimating the resolution of an ultrasound image of a baby if the image size is about 250 mm across and high by a square array of 256×256
- Solving problems and analysing information using acoustic impedance
- Discussing and observing two X-ray radiographic images with and without showing bone fracture
- Discussing the question: “As late as the 1950s X-rays were used to ensure well-fitting shoes. Why is this no longer the case today?”
- Gathering information about deaths due to tuberculosis in the 1940s and suggesting a method to diagnose the disease so as to reduce risk

- Using a dental film and a gamma source to demonstrate film exposure of X-rays and absorption of X-rays
- Observing a CT scan image and comparing the information provided by CT scans to that provided by an conventional X-ray radiographic image for the same body part
- Performing a first-hand investigation to demonstrate the transfer of light beam by optical fibres
- Gathering information to observe internal organs from images produced by an endoscope
- Using dice to simulate radioactive decay and study the random nature of decay in radioactive nuclides
- Comparing a gamma camera scanned image of bone with an X-ray radiographic image
- Comparing a gamma camera scanned image of one healthy body part or organ with a scanned image of its diseased counterpart
- Comparing the advantages and disadvantages of conventional X-ray radiographic images and CT scans
- Gathering and analysing information and using available evidence to assess the impact of medical applications of physics on society
- Discussing the issues related to radiation safety using non-ionizing radiation and ionizing radiation for imaging
- Reading articles from the e-museum (http://nobelprize.org/nobel_prizes/physics/) to trace the historic development of CT, explore what physicists do and the impact of scientific thought on society

Values and Attitudes

Students should develop positive values and attitudes through studying this topic. Some particular examples are:

- to be aware of the importance of safety measures in relation to ionizing and non-ionizing radiation
- to be aware of the potential danger from X-rays and radiation from radioactive sources to pregnant woman
- to adopt a cautious attitude in matters concerning public safety
- to be aware of the implications of the use of different modes of imaging technology and to make an effort to reduce radiation exposure in daily life
- to appreciate some of the factors which contribute to good health, and the importance of personal responsibility in maintaining it
- to appreciate the role of the medical and associated services provided in Hong Kong and

the role of various people within them

- to appreciate the relative importance of preventative and curative services
- to be open-minded in evaluating potential applications of physics to new medical technology
- to appreciate the efforts made by scientists to find alternative methods of medical diagnosis
- to appreciate that important scientific discoveries (such as radioactivity and X-rays) can ultimately have a huge impact on society
- to appreciate the contributions of physics, mathematics, engineering and computer science to revolutionising the technology used in medical imaging
- to recognise the roles of science and technology in the exploration of medical science and to appreciate the efforts undertaken to understand the human body
- to recognise the importance of lifelong and independent learning in a knowledge-based society

STSE connections

Students are encouraged to develop an awareness and understanding of issues associated with the interconnections among science, technology, society and the environment. Some examples of such issues related to this topic are:

- the issue of the effects of radioactive waste from medical applications on the environment
- the issue of who decides how much money is spent on medical research
- how often patients should be screened using X-rays in possible cases of tuberculosis (TB)
- how dangerous or risky the use of X-rays, ultrasound and radionuclides is for patients
- how abnormality in the foetus can be detected
- the issue of using CT scan in archaeological investigations
- medical diagnosis: the dilemma in choosing between various devices for the optimum result
- accepting uncertainty in description and explanation of pathology by medical diagnosis, and the issue of false positive and false negative
- the ethical issue of a doctor deciding whether or not to turn off a life-support machine

2.3.3 Investigative Study (16 hours)

X Investigative Study in Physics (16 hours)

Overview

This study aims to provide students with an opportunity to design and conduct an investigation with a view to solving an authentic problem. Investigative studies are inquiry-oriented activities to provide students with direct exposure to experiences that reinforce the inquiry nature of science. In the task, students have to analyse a problem, plan and conduct an investigation, gather data, organise their results, and communicate their findings. In this connection, students are involved actively in their learning, formulating questions, investigating widely and then build new ideas and knowledge.

A portion of the curriculum time is set aside for this purpose. Students are expected to make use of their knowledge and understanding of physics, together with generic skills (including but not limited to creativity, critical thinking, communication and problem-solving) in a group-based investigative study. Through the learning process in this study, students can enhance both their practical and non-practical skills, and develop an awareness of the need to work safely in investigations.

The following learning outcomes are expected:
Students should be able to

- justify the appropriateness of an investigation plan
- put forward suggestions for ways of improving the validity and reliability of a scientific investigation
- use accurate terminologies and appropriate reporting styles to communicate findings and conclusions of a scientific investigation
- evaluate the validity of conclusions with reference to the process of investigation and the data and information gathered
- demonstrate mastery of manipulative and observation skills, and also good attitudes in general
- show appropriate awareness of the importance of working safely in the laboratory and elsewhere

Implementation

***Prerequisites* –** Students should have some insight into and experience of the following aspects before conducting an investigative study:

- Selecting an appropriate question for the task
- Searching for relevant information from various sources
- Writing an investigation plan
- Writing up a laboratory report or making a poster for presentation

***Grouping* –** The investigation can be conducted in groups of four to five students.

***Timing* –** The investigation can be undertaken on completion of a task requiring students to plan an experiment for an investigative study, indicating the variables to be measured, the measurements they will make, and how they will record and present the data collected. For instance, an investigative study on the topic "projectile motion" can be carried out towards the end of S5 and completed at the start of S6. Students can develop their investigation plan from March to May of S5. The investigation can be conducted at the end of S5; and the presentations can be given at the start of S6. Alternatively, it is possible to conduct an investigation in conjunction with the learning of a topic. Investigations, then, can be conducted in S5 and completed in S6.

Time is allocated for the following activities:

- Searching and defining questions for investigations
- Developing an investigation plan
- Conducting the investigation
- Organising, documenting and analysing data for a justified conclusion
- Presentation of findings and writing reports/making posters

***Suggestions* –** The topics selected should be related to practical work. The study should focus on authentic problems, events or issues which involve key elements such as "finding out" and "gathering first-hand information". In addition, to maximise the benefit of learning from the investigation within the time allocated, teachers and students should work together closely to discuss and decide appropriate and feasible topics.

Some possible topics for investigative studies are suggested below:

- Building a box which has the best effect in keeping the temperature of an object steady, or the best cooling effect
- Measuring the distance between two points which are very far away (e.g. the distance between the Earth and the Moon)
- Measuring the height and size of a building
- Examining the principles and applications of a solar cell
- Constructing and testing a home-made wind turbine
- Measuring the speed of a water rocket
- Studying articles about the latest discoveries in astronomy
- Investigating the principles of nanoscience in commercial products by the use of various properties of nano materials, (e.g. permeability to gas, water-repellence and transparency)
- Reading articles from the e-museum (http://nobelprize.org/nobel_prizes/physics/) to trace the historic development of CT, particularly memorable descriptions of what physicists have done and the impact of scientific thought on society

Assessment

To facilitate learning, teachers and students can discuss and agree on the following assessment criteria, taking into account factors that may help or hinder the implementation of the study in particular school environments.

- Feasibility of the investigation plan
- Understanding of the relevant physics concepts, and concerns about safety
- Effective use of manipulative skills
- Demonstration of positive attitudes
- Proper data collection procedures and ways to handle possible sources of error
- Ability to analyse and interpret data obtained from first-hand investigation
- Ability to evaluate the validity and reliability of the investigation process and the findings
- Ability to communicate and defend the findings to the teacher and peers
- Appropriateness of references used to back up the methods and findings

A number of assessment methods such as observation, questioning, oral presentation, poster presentation sessions and the scrutiny of written products (e.g. investigation plan, reports and posters) can be used where appropriate.

Chapter 3 Curriculum Planning

This chapter provides guidelines to help schools and teachers to develop a flexible and balanced curriculum that suits the needs, interests and abilities of their students, and the context of their school, in accordance with the central framework provided in Chapter 2.

3.1 Guiding Principles

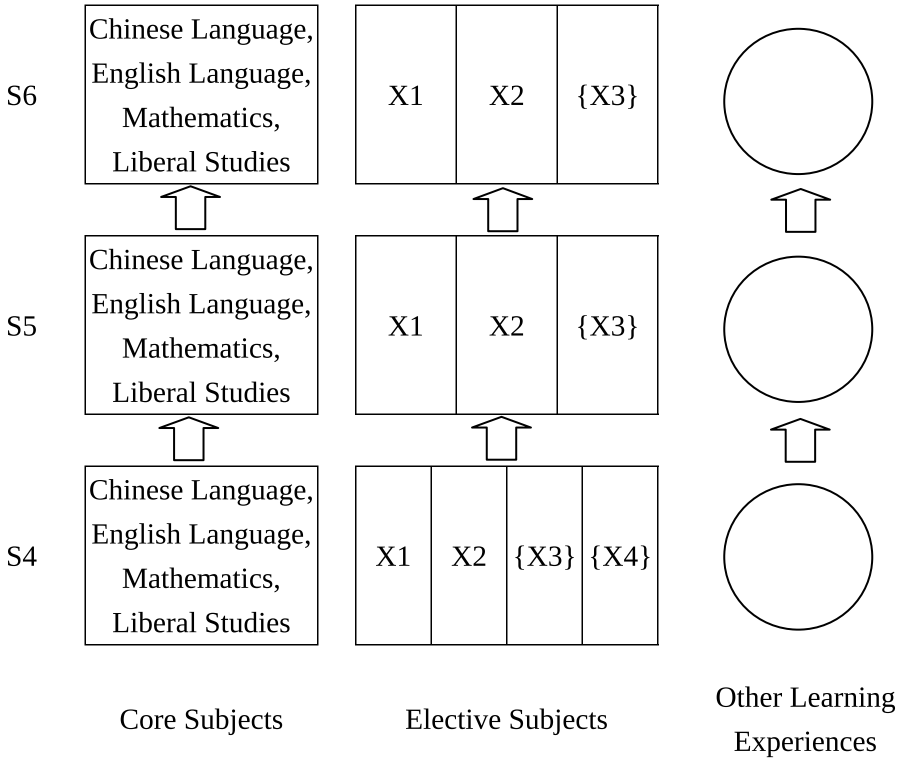
As a senior secondary science subject in the Science Education KLA, Physics builds on the junior secondary Science Curriculum. This chapter describes the linkages of knowledge, concepts, process skills and generic skills between the two levels of study. Teachers may consider the details given in this chapter as a reference for planning their Physics Curriculum for their students. Schools and teachers are encouraged to:

- facilitate continuity with the junior secondary Science Curriculum through a comprehensive coverage of the learning targets to promote integrative use of skills and a balanced development of learning experiences;
- plan and devise appropriate and purposeful learning and teaching materials, practical work, scientific investigations and projects to develop students' knowledge and understanding, skills and processes, values and attitudes, problem-solving skills, critical thinking skills, creativity, and strategies for learning to learn;
- set and work on clear and manageable curriculum goals to develop a progressive and appropriate curriculum that serves to bring about pleasurable, meaningful and productive learning experiences;
- make flexible use of lesson time to facilitate learning; and
- review and plan the curriculum flexibly and make appropriate re-adjustments when necessary, taking into account the SBA implementation arrangements for the subject as specified in Chapter 5 – Assessment.

Students have different interests, strengths, aspirations and learning styles – visual, auditory, and kinaesthetic and tactile, as well as different science concepts. It is, therefore, desirable to organise the curriculum in a way that addresses the individual needs of students. Some teachers may prefer certain learning and teaching approaches to others, and believe that these approaches help to enhance the effectiveness, efficiency and quality of student learning. Teachers are encouraged to organise the curriculum in meaningful and appropriate ways to ensure "fitness for purpose".

3.2 Progression

To help students with different aptitudes and abilities to explore their interests in different senior secondary subjects, the *334 Report* recommends the idea of “progression” as illustrated in Figure 3.1.



X represents an elective subject and { } indicates optional

Figure 3.1 Diagrammatic Representation of Progression

In short, schools can offer their students a total of four elective subjects at S4 level, three at S5 level and three at S6 level respectively.

With the approach suggested above, a number of topics have been identified from the curriculum, to allow students, to explore their interests in science subjects. These topics should help to lay the foundation for learning physics and promote lifelong and independent learning in science and technology. A possible arrangement of the topics is described in Figure 3.2. Schools can consider whether this arrangement will facilitate progression for their senior secondary students.

Topics for possible introduction in S4		Remarks
I	Heat and Gases a. Temperature, heat and internal energy b. Transfer processes c. Change of state d. Gases	All subtopics are included except subtopic (d) which may be introduced at a later stage after the learning of momentum.
II	Force and Motion a. Position and movement b. Force and motion c. Projectile motion d. Work, energy and power e. Momentum f. Uniform circular motion g. Gravitation	Subtopics (a), (b) and (d) can be introduced in S4 while other subtopics may be studied at an early stage of S5 after students have a good understanding in Mechanics.
III	Wave Motion a. Nature and properties of waves b. Light c. Sound	Concepts in some subtopics (e.g. diffraction, interference, diffraction grating) are abstract, and so should be introduced at a later stage.
X	Investigative Study in Physics	This can be introduced together with basic scientific skills and practical skills but not for assessment.

Figure 3.2 Possible Arrangement of Topics in S4

Considering the rapid advances in the world of science and technology, many contemporary issues and scientific problems have to be tackled by applying science concepts and skills acquired in a wide range of contexts. Hence it benefits students to gain a broad learning experience in the three disciplines in science – biology, chemistry and physics.

To cater for students who are interested in learning science and intend to take two to three science subjects, it is suggested that schools offer a broad and balanced science curriculum for students in S4, including all the three selected parts from Biology, Chemistry and Physics. In this way, students will gain a good understanding of the different nature and requirements of the respective disciplines, and will be more able to identify their interests and strengths for choosing their specialised study in higher forms.

Figure 3.3 below is an example on how schools can organise progression of study for students who wish to learn more science.

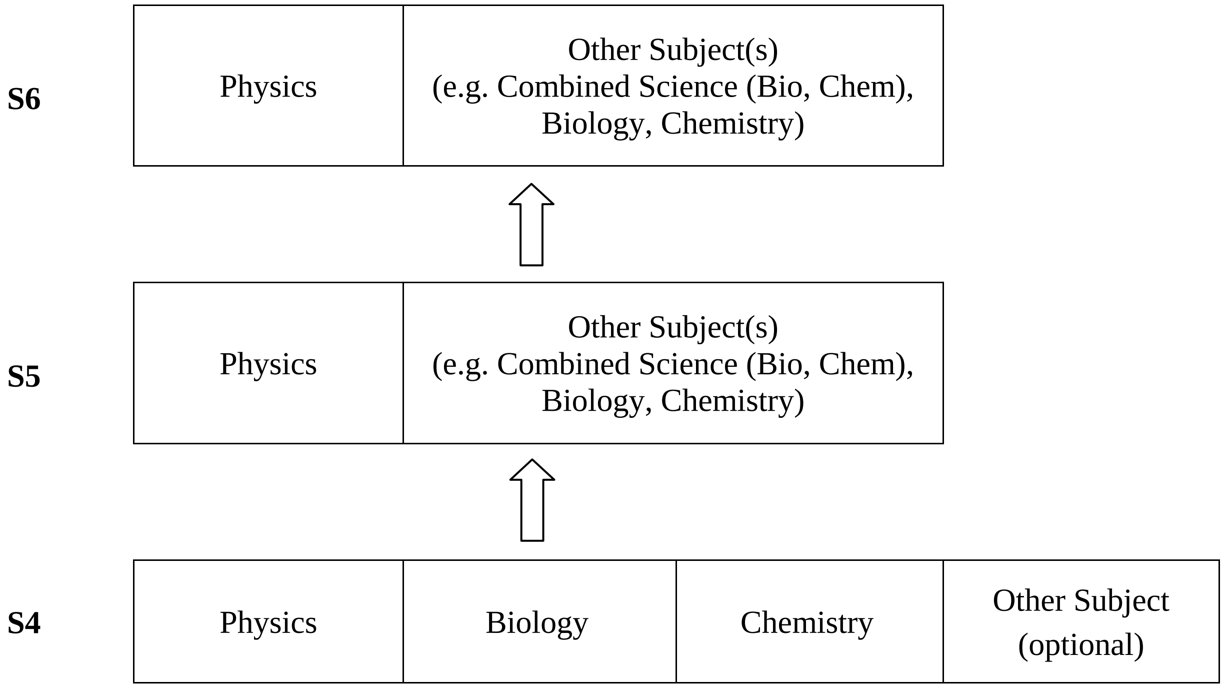


Figure 3.3 Progression of Study in Science Subjects

In the senior secondary academic structure, there will be flexibility to allow students to take up the study of Physics in S5. For these students, a similar sequence of learning still applies. Schools may consider allocating more learning time and providing other supporting measures (e.g. bridging programmes) for such students so that they can catch up on the foundation knowledge and skills as soon as possible.

3.3 Curriculum Planning Strategies

3.3.1 Interface with the Junior Secondary Science Curriculum

This curriculum builds on the *Syllabuses for Secondary Schools – Science (Secondary 1-3)* (CDC, 1998). The junior secondary Science Curriculum starts with the topic "Energy" which helps students to appreciate energy as one of the fundamentals of physics, learn some basic knowledge of physics, acquire some basic practical skills and develop positive attitudes towards physics. Furthermore, through the study of this curriculum, students can consolidate their knowledge and understanding of physics and build on the scientific skills acquired in their junior science course.

Students should have developed some basic understanding of physics through their three-year junior secondary science course. The learning experiences acquired provide a concrete foundation and serve as "stepping stones" for senior secondary physics. Figure 3.4 shows how the respective physics topics in the Science (S1–3) Syllabus are related to different topics in this curriculum.

Science (S1–3)		**Physics**	
Unit	Title	Topic	Title
1.4	Conducting a simple scientific investigation	X	Investigative Study in Physics
4.1	Forms of energy	VIII	Energy and Use of Energy and other parts in the curriculum
4.2	Energy changes		
4.4	Generating electricity		
4.5	Energy sources and we		
6.1	States of matter	I	Heat and Gases
6.2	Illustrations for the support of the claims of the particle theory		
6.3	Particle model for the three states of matter		
6.4	Gas pressure		
8	Making use of electricity	IV	Electricity and Magnetism
9.1	Forces	II	Force and Motion
9.2	Friction		
9.3	Force of gravity		
9.4	A space journey	I	Heat and Gases
9.5	Life of an astronaut in space	II	Force and Motion
9.6	Space exploration	VI	Astronomy and Space Science
11.2	How we see	III	Wave Motion
11.3	Limitations of our eyes	IX	Medical Physics
11.4	Defects of the eye		
11.5	How we hear		
11.6	Limitations of our ears		
11.7	Effects of noise pollution		
15	Light, colour and beyond	III	Wave Motion

Figure 3.4 Relationship between Science (S1-3) Syllabus and Physics Curriculum

3.3.2 Suggested Learning and Teaching Sequences

This chapter illustrates how teachers may approach their learning and teaching strategies, and curriculum planning. The essence of physics lies in the creation of concepts, models and theories which should be consistent and matched with observations. It is worthwhile to note that concepts or principles are special forms of knowledge for enhancing students' understanding of physics. In order to make the learning and teaching of physics effective, and be aware of students' learning difficulties and misconceptions, a constructivist approach is recommended. Making use of contextualised examples which are related to key concepts in the curriculum enables meaningful student learning. Students have a number of intuitive ideas about the physical world based on their everyday experience; and developing concepts within a familiar context provides an opportunity for them to become more aware of their intuitive ideas. In addition, by connecting key concepts with the historic process through which physics has developed, teachers should be in a better position to anticipate and understand students' intuitive ideas, which often align with historical controversies. Some of the suggested topics should permeate the whole curriculum so that students come to appreciate interconnections between different topics. The sequence is organised so that learning starts with topics with more concrete content and less difficult concepts, and then progresses onto topics that are more abstract and subtle. For example, students need to understand the concept of momentum before they can appreciate the kinetic model of gases.

Topics like "Temperature, heat and internal energy", "Transfer processes", "Change of state", "Position and movement", "Force and motion", "Work, energy and power" and "Light" give rise to a vast amount of concrete relevant contextualised examples, which help students to construct concepts at S4 level. These examples can provide opportunities to connect concepts and theories discussed in the classroom and textbooks with daily observations of phenomena. Teachers may help students by providing or having them construct conceptual organisers such as concept maps to foster the learning of physics. Students often find Newton's laws of motion counter-intuitive, and studying two dimensional projectile motion adds further complications. To ensure meaningful learning, teachers need to check what prerequisite knowledge students have, and then structure the problem in small manageable steps which take the form of a simple sequencing task. Students can review their previous learning and prior knowledge at different stages of learning. For example, teachers introduce preliminary basic concepts of force and motion in S4, and refine these concepts in S5.

The Physics Curriculum provides a flexible framework within which schools can design learning sequences suited to the needs of their students. Teachers can consider whether or not to adopt the sequence suggested, and are reminded that they can exercise their professional judgment to design the most appropriate learning and teaching sequence. It is likely that for different ability groups to gain full benefit, different learning sequences will need to be adopted in schools. Through the study of the various topics in the compulsory and elective parts, students should develop progressively more and more sophisticated concepts in physics. The following teaching sequence is therefore given as a suggestion only.

<table>
<tr><th colspan="3">Topics</th><th>Level</th></tr>
<tr><td>I</td><td colspan="2">Heat and Gases (except gases)</td><td rowspan="4">S4</td></tr>
<tr><td>II</td><td colspan="2">Force and Motion (except projectile motion, momentum, uniform circular motion and gravitation)</td></tr>
<tr><td>III</td><td colspan="2">Wave Motion (light only)</td></tr>
<tr><td>X</td><td colspan="2">Investigative Study in Physics</td></tr>
<tr><td>II</td><td colspan="2">Force and Motion (projectile motion, momentum, uniform circular motion and gravitation)</td><td rowspan="5">S5</td></tr>
<tr><td>I</td><td colspan="2">Heat and Gases (gases)</td></tr>
<tr><td>III</td><td colspan="2">Wave Motion (except light)</td></tr>
<tr><td>IV</td><td colspan="2">Electricity and Magnetism</td></tr>
<tr><td>X</td><td colspan="2">Investigative Study in Physics</td></tr>
<tr><td>V</td><td colspan="2">Radioactivity and Nuclear energy</td><td rowspan="6">S6</td></tr>
<tr><td>VI</td><td>Astronomy and Space Science</td><td rowspan="4">Elective part
(2 out of 4)</td></tr>
<tr><td>VII</td><td>Atomic World</td></tr>
<tr><td>VIII</td><td>Energy and Use of Energy</td></tr>
<tr><td>IX</td><td>Medical Physics</td></tr>
<tr><td>X</td><td colspan="2">Investigative Study in Physics</td></tr>
</table>

Figure 3.5 Suggested Learning and Teaching Sequence for the Physics Curriculum

Besides the suggestions mentioned above, teachers can also consider the following ideas on planning their curricula for their particular groups of students.

(1) Curriculum organisation

One important aspect in the teaching of topics, especially at S4 level, is to find the most appropriate level of simplification of the subject matter. For example, when students are studying the concept of "heat" in physics, some key ideas are essential and should be introduced at S4 level, while other more complex concepts should be deferred until later. The curriculum should balance breadth and depth so that students can understand its content. From this perspective, teachers should judge the appropriate level of simplification, the order in which to present ideas, and the pace at which to deliver the key ideas in order to help students to construct as scientifically valid a model of a topic as possible.

Figure 3.6 below shows one possible simplification to relate heat, temperature and internal energy. In this case, heat flows due to a temperature difference and this can lead to a change in temperature, or a change of state. This is explained in terms of a kinetic model, where the heat flow increases the internal energy of the particles. The internal energy of the particles can be kinetic and potential, and the temperature is a measure of the average kinetic energy of the particles. This scheme may be considered as a concept map, with each arrow representing a relationship between the concepts in the boxes connected. It should be noted that students may need prior knowledge – for example of kinetic energy and potential energy in the topic "Force and Motion" – to understand the concept of internal energy of particles. This part of "Heat and Gases" may run concurrently with "Force and Motion".

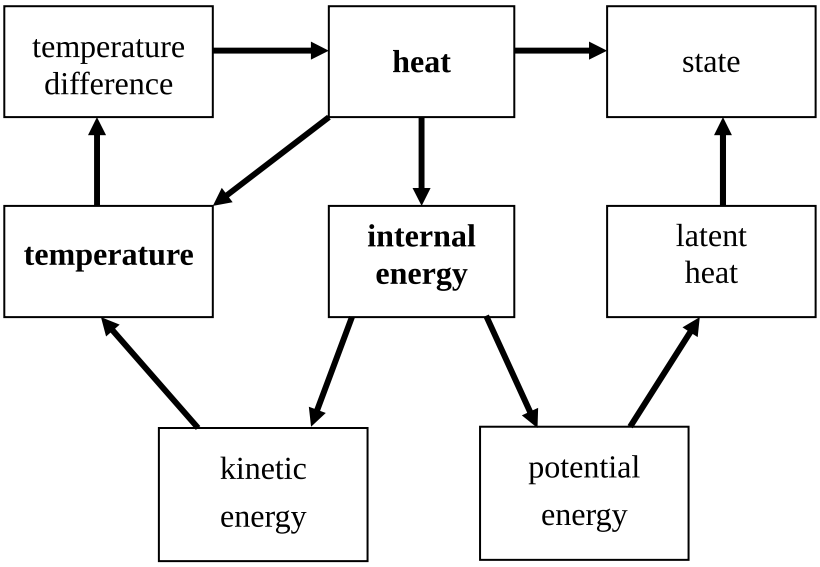


Figure 3.6 Concept Map showing the Relationship between Heat, Temperature and Internal energy

(2) Integration of major topics

The curriculum includes compulsory and elective parts. The compulsory part provides fundamental concepts of physics in S4 and S5, followed by a range of topics in the elective part from which students must choose any two. The topics in the elective part can be used as vehicles for teaching areas of special interest to students. This provides excellent opportunities to introduce and extend key concepts. For instance, knowledge and concepts, such as the nature and properties of waves, light and sound in “Wave Motion” are further reinforced in “Medical Physics”, where medical imaging using non-ionizing and ionizing radiations is used as an extension task. Extension tasks are demanding and can stretch students’ ability. The purpose of this arrangement is to avoid loading students with many abstract concepts in a short period of time, particularly, at the early stage of senior secondary study, and it also aims to provide opportunities for students to revisit their learning in S5. Some teachers may prefer to introduce the concepts related to wave motion all at one time, and others may organise their own curriculum so that the topics “Wave Motion” and “Medical Physics” run concurrently. Similar integration can be extended to topics such as “Electricity and Magnetism” and “Energy and Use of Energy”, “Force and Motion” and “Astronomy and Space Science”, as well as “Radioactivity and Nuclear Energy” and “Atomic World”.

(3) Integration of the Investigative Study with major topics

Inquiry activities have a central and distinctive role in physics education. The interaction among theories, experiments and practical applications is fundamental to the progress of physics. Teachers can encourage students to reconstruct their knowledge using inquiry activities within a community of learners in the classroom and on the basis of personal experience. Meaningful learning can occur if students are given sufficient time and opportunity for interaction and reflection, with the generic skills being further enhanced and extended. The “Investigative Study in Physics” is an opportunity for students to apply their physics knowledge in scientific investigation to solve an authentic problem. The learning in different parts of the curriculum together with the experience in the Investigative Study, should pave the way for students to become self-directed and competent lifelong learners. Teachers may encounter students, who are mathematically inclined, and intend to carry out simulations on data modelling. To cater for the needs of these students, teachers can organise the learning of the topics in the elective part (e.g. “Astronomy and Space Science") in parallel with the Investigative Study. In simulation runs, the students explore the relationship between assumptions and predictions about a phenomenon, which helps them to apply physics concepts to analyse and solve problems, and at the same time develops various generic skills. Teachers can also adopt an alternative learning and teaching strategy. For example, by solving problems through gathering information, reading critically, learning new knowledge on their own, discussion, and investigation, students can master the knowledge and understanding required in the Investigative Study for the topic “Energy and Use of Energy”. Similar integration can also be extended to other topics in the compulsory part and the elective part, including “Atomic World” and “Medical Physics”.

3.3.3 Curriculum Adaptations for Learner Diversity

The curriculum needs to be adapted to cope with learner diversity in interests, academic readiness, aspirations and learning style. On the one hand, it is necessary to cater for students with a strong interest or outstanding ability in physics by setting more challenging learning targets on top of those described in this Guide. For such students, teachers should design and implement a curriculum which does not deprive them of learning opportunities to develop their full potential. On the other hand, teachers may need to design and implement a curriculum to facilitate the learning of some students who can master only some of the concepts and skills described in this Guide. This curriculum has been designed in such a way that teachers can make their own judgments about the appropriate depth of treatment for topics or subtopics for their students. In short, this Guide is intended to be a reference for teachers planning a curriculum for their own students, but not a prescription for all.

This curriculum can be adapted in a number of ways such as focusing learning on the topics in the compulsory part and putting less emphasis on those in the elective part. This suggestion is not intended to deprive students of opportunities for in-depth learning of the curriculum, but rather, to encourage them to focus their learning in order to build up sound fundamental knowledge and skills. Teachers can consider the following suggestions when planning how to adapt the curriculum for students with different needs.

- If students have difficulty in mastering the whole curriculum, teachers and students can work out the appropriate level of study for all the topics in the compulsory part. Figure 3.7 shows the topics in the extension component of the compulsory part which are considered to be cognitively more demanding. Students may need extra support to master the necessary knowledge and understanding in these topics.

Topic	*Extension topics in the compulsory part*
I.	Gases
II.	Projectile motion; Momentum; Uniform circular motion and Gravitation
III.	Formation of images by lenses (formula) and Wave nature of light (calculation)
IV.	Electric field strength; Magnetic flux; Faraday's Law; Alternating currents; Transformer and High voltage transmission of electrical energy
V.	Radioactive decay (exponential law of decay and decay constant) and Mass-energy relationship

Figure 3.7 Extension Topics in the Compulsory Part

- Where students are found to experience significant difficulty in coping with the whole curriculum, teachers and students can discuss and agree on alternative arrangements such as putting minimum effort into, or skipping, the topics in the elective part.

To cater for diversity among students, teachers are encouraged to adapt the design of their curricula in the above ways. Teachers should evaluate their own curriculum against the following guidelines:

- The curriculum should be aligned with the overarching aims and learning targets;
- The curriculum should be broad and balanced;
- Learning targets should be achievable and not too demanding; and
- The learning activities included should arouse student interest and be enjoyable.

3.3.4 Flexible Use of Learning Time

As mentioned in Chapter 2, a total of 250 hours or 10% of the overall lesson time should be allocated to cover the curriculum. Teachers are encouraged to use this time flexibly to help students to attain all the different targets of the curriculum. Since students' interests are very diverse, they may find some of the topics more interesting and be more motivated to explore deeper into these. Thus, more time will be spent on them than on others. Besides, some schools may allocate more lesson time for the study of the compulsory part to ensure students are equipped with sound fundamental knowledge and skills before starting the elective part. The 16 hours allocated to the investigative study can be taken advantage of and be used flexibly to promote student learning and develop the full range of skills. Schools are also encouraged to include half-day or whole-day activity sessions (shared among different KLAs) in the school time-table, to allow continuous stretches of time for field trips, visits or scientific investigations.

3.4 Curriculum Management

3.4.1 Effective Curriculum Management

Effective curriculum management facilitates effective learning and teaching in schools. In order to manage the curriculum effectively, curriculum leaders in a school have to work together in school-based curriculum development and take the following aspects into consideration.

(1) Understanding the curriculum and student needs

The Physics Curriculum describes the rationale, curriculum aims, learning targets, curriculum structure and organisation, curriculum planning, learning and teaching as well as assessment for Physics. A good understanding of the Physics Curriculum, the needs and interests of students as well as the strength and culture of the school will facilitate effective school-based curriculum development and the alignment of learning and teaching with the school vision and mission as well as with the central curriculum framework.

(2) Organisations and structure

Different curriculum leaders including coordinators of Science Education KLA, physics panel chairperson and physics teachers have to work together as a team and play different roles in managing the school-based curriculum development. In addition to oversee and coordinate the implementation of the curriculum, coordinators of Science Education KLA and panel chairpersons have to develop a plan for enhancing teamwork and the professional capacity of their teachers.

(3) Curriculum planning

Schools have to develop a holistic plan for school-based curriculum development to ensure vertical and lateral coherence among different science subjects and between science and other subjects. It is important to plan for interface with the junior secondary Science Curriculum and provide a balanced foundation in science education for students. Details about curriculum planning strategies are described in Section 3.3.

(4) Capacity building and professional development

Team building can be enhanced through the regular exchange of ideas, experiences and reflections in collaborative lesson preparation, peer coaching and lesson observation. It is important to foster a collaborative and sharing culture among teachers and to facilitate their professional development. Besides, schools should create space for teachers to participate in various professional development programmes and deploy teachers appropriately and flexibly according to their strengths.

(5) Resource development

Learning and teaching resources that facilitate learning will be developed by the EDB to support the implementation of the curriculum. Schools are encouraged to adapt these resources or to develop their own learning and teaching materials to meet the needs of their students. These materials could be shared among teachers through the development of a school-based learning and teaching resources bank or a sharing platform in the school

Intranet. Details about the effective use of learning and teaching resources are described in Chapter 6.

(6) Managing change

In view of the dynamic nature of physics knowledge and the changing concerns of contemporary society, schools should define the scope and direction of curriculum development with a degree of certainty but the implementation of the curriculum needs to be flexible enough to enable learning from experience and coverage of burning issues. Effective strategies for managing change include participation and communication, periodic review to monitor progress and the collection of evidence on the basis of which it is possible to make improvements.

3.4.2 Roles of Different Stakeholders in Schools

In schools, curriculum leaders take up different roles in managing curriculum change and the roles they assume may vary depending on the school context.

(1) Physics Teacher

Physics teachers can contribute to the development of the school-based physics curriculum by working in line with the school policy and assisting the panel chairperson in collaboration with other physics teachers. Physics teachers can work in collaboration with supporting staff to design interesting activities and a safe environment conducive to learning. They can initiate innovative curricular changes themselves or in partnership with others.

To implement the Physics Curriculum effectively, teachers should:

- explain clearly to students the overall plan and purpose of the Physics Curriculum;
- provide adequate guidance and support to students so as to achieve learning targets set out in the Physics Curriculum;
- foster a motivating learning environment among students and empower students self-directed learning;
- try out and work on innovative learning and teaching strategies;
- initiate sharing of ideas, knowledge and experiences to foster peer support and improvement in teaching and learning;
- keep abreast of the latest curriculum developments and changes through reading and sharing among fellow teachers;
- participate actively in professional development courses, workshops, seminars etc. to

enhance professionalism;

- ensure students take adequate safety measures for the proper conduct of practical and investigative activities; and
- review or evaluate the school-based physics curriculum from time to time for improvements.

(2) Science Education KLA Coordinator/Physics Panel Chairperson

The Science Education KLA coordinator/physics panel chairperson plays a significant role in developing and managing the Physics Curriculum as well as facilitating its implementation. They act as the “bridge” between the school administrative personnel and other science panel members to enhance effective collaboration.

To develop and manage the physics curriculum in schools, as well as monitoring its implementation, physics panel chairpersons should lead the panel to:

- assist in the development of a holistic plan for a balanced science education by making use of the guidelines set out in the *Science Education KLA Curriculum Guide (P1-S3)* (CDC, 2002a) and related C&A Guides;
- plan and provide an appropriate physics programme to promote effective learning of subject knowledge as well as development of generic skills, scientific process skills, and values and attitudes by making use of the guidelines set out in the Physics Curriculum framework;
- facilitate effective collaboration and communication among school administrative personnel and other science panel members for the overall implementation of science education in schools;
- decide on the topics in the Elective Part to be offered for a balanced learning experience within the Physics Curriculum, taking into account students’ needs, interests and abilities as well as panel members’ strength and the school context;
- meet regularly with panel members to discuss matters such as curriculum planning, assessment policies, use of learning and teaching materials, adoption of learning and teaching strategies, review of progress, and to further explore curriculum implementation strategies to enhance the effectiveness of learning and teaching;
- promote regular exchange of learning and teaching ideas, experiences and reflections by various means such as collaborative lesson preparation, peer coaching and lesson observation;
- facilitate professional development by encouraging panel members to participate in professional development courses, workshops, seminars and projects;
- ensure sufficient resources to support the implementation of the curriculum and maximise

their usage (e.g. laboratory facilities and equipment, laboratory technicians and IT equipment); and

- ensure safety and precautionary measures are taken for the conduct of practical work and scientific investigations.

(3) School Head

School heads take the leading role in directing, planning and supporting overall school-based curriculum development according to the central curriculum guide. They need to understand the central curriculum framework and be well aware of contextual factors such as the needs of the students, the strengths of teachers and the organisational culture of the school. With regard to Science Education, school heads are encouraged to work closely with their Deputy Heads or Academic Masters/Mistresses to carry out the following roles as curriculum leaders:

- understand the full picture and define the scope of curriculum development for the Science Education KLA and align it with the vision and mission;
- clarify the roles and responsibilities of coordinators and panel chairpersons of the Science Education KLA;
- adopt flexible time-tabling to facilitate the implementation of the Combined Science mode to complement the learning of Physics in order to provide a balanced foundation in science for students;
- deploy school resources appropriately (e.g. laboratory supporting staff and equipment) to facilitate effective learning and teaching;
- promote a collaborative and sharing culture among teachers by encouraging collaborative lesson preparation and peer lesson observation;
- create space for teachers to participate in professional development programmes;
- appreciate and commend progress made, treasuring quality rather than quantity, and sustain appropriate curriculum initiatives;
- help parents and students to understand the school's beliefs, rationale and practices in the implementation of the curriculum, and their roles in facilitating learning; and
- network with other schools to promote professional exchange of information and the sharing of good practices.

Details about the roles of teachers, KLA coordinators, panel chairpersons and school heads as the key change agents are described in Booklet 9 of the *Senior Secondary Curriculum Guide* (CDC, 2009).

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Chapter 4 Learning and Teaching

This chapter provides guidelines for effective learning and teaching of the Physics Curriculum. It is to be read in conjunction with Booklet 3 in the *Senior Secondary Curriculum Guide* (CDC, 2009), which provides the basis for the suggestions set out below.

4.1 Knowledge and Learning

As discussed in Chapter 1, students have to adapt to a highly competitive and integrated economy, ongoing scientific and technological innovation, and a rapidly growing knowledge base. Even though Physics is a well-established discipline, the knowledge of physics is continuously evolving. This is well demonstrated by, for example, the discovery of the atomic structure, starting from J. J. Thomson's discovery of electrons at the end of the nineteenth century and the breakthrough of Ernest Rutherford's atomic model in early twentieth century to the recent discoveries in particle physics.

Learning may take place in various ways, for example through direct instruction, involvement in a learning process or co-construction of knowledge. For instance, in an authentic investigation of means to verify the independence of vertical and horizontal motions of an object under projectile motion, much of the learning can take place through direct instruction in combination with co-construction. Students can learn about common methods used for verification through direct instruction by the teacher; while new knowledge can be co-constructed through interaction between students and teacher to explore innovative methods and tools used for this purpose.

The roles of teachers and students change in accordance with the objectives and types of learning activities. Teachers' roles can range from being transmitters of knowledge to acting as resource persons, facilitators, consultants, counsellors, assessors, and very often a mixture of some of these. In some contexts, students may be attentive listeners, while in others they need to be active, independent and self-directed learners.

4.2 Guiding Principles

Some key guidelines for learning and teaching the subject are listed below, which take into account the recommendations in Booklet 3 of the *Senior Secondary Curriculum Guide* (CDC, 2009) and the emphases in the Science Education KLA.

(1) Building on strengths

In learning science, most Hong Kong students are strong in memorising content knowledge, analysing numerical data and understanding scientific concepts. Many local teachers view these processes as interlocking. The strengths of Hong Kong students and teachers should be acknowledged and treasured.

(2) Prior knowledge and experiences

Learning and teaching activities should be planned with due consideration given to students' prior knowledge and experiences.

(3) Understanding learning targets

Activities should be designed and deployed in such a way that the learning targets are clear to both the teacher and the students.

(4) Teaching for understanding

Activities should aim at enabling students to act and think flexibly with what they know.

(5) A wide range of learning and teaching activities

A variety of activities which involve different pedagogies should be deployed so that different learning targets can be attained effectively. There is more discussion on pedagogy later in this chapter.

(6) Promoting independent learning

Activities that nurture generic skills and thinking skills should be used in appropriate learning contexts of the curriculum to enhance students' capacity for independent learning.

(7) Motivation

Students learn best when they are motivated. Learning activities should build on students' successful experiences and meet their needs and interests.

(8) Engagement

Activities should aim to engage all students actively in the learning process. Examples and topics related to daily life and familiar contexts help students to see the relevance of their learning.

(9) Feedback and assessment

Providing immediate, effective feedback to students should be an integral part of learning and teaching. In addition, strategies for "assessment *for* learning" and "assessment *of* learning" should be used where appropriate.

(10) Resources

A variety of resources can be employed flexibly as tools for learning. Suggestions on resources which can be used to enhance the quality of learning are given in Chapter 6.

(11) Catering for learner diversity

Students have different characteristics and strengths. Appropriate learning and teaching strategies should be used to cater for learner diversity.

4.3 Approaches and Strategies

4.3.1 Approaches to Learning and Teaching

Broadly speaking, there are three different common and intertwined approaches to learning and teaching Physics.

(1) "Teaching as direct instruction"

"Teaching as direct instruction" is perhaps the best known approach. It involves teachers transmitting knowledge directly to their students. This kind of learning and teaching approach is common in Hong Kong classrooms, where students in general like to get considerable guidance from their teachers. Direct instruction, if appropriately used in an interactive manner, is a powerful tool to help learning. Well organised content, contextualised examples and a vivid interactive presentation with clear focuses are important features of successful direct instruction. It can be used in many situations in physics lessons, e.g. introducing symbols of physical quantities, exposition of abstract physics theories and sophisticated debriefings of difficult topics at the end of a lesson.

(2) "Teaching as inquiry"

"Teaching as inquiry" is advocated by many educators who believe that knowledge is best constructed through individual learners' effort and activity. This is a more student-centred approach. It advocates the use of learning activities such as simple problem-solving tasks which require various cognitive abilities, and inquiry-based experiments which involve hypothesis testing, designing working procedures, gathering data, performing calculations and drawing conclusions. The "Investigative Study in Physics" discussed in Chapter 2 is an example on how "teaching as inquiry" can be implemented in classrooms.

(3) "Teaching as co-construction"

"Teaching as co-construction" is an approach which sees learning as a social interactive process in which teachers may also act as learners. This view stresses the value of students sharing their knowledge and generating new knowledge through group work, with the teacher as a learner partner providing support. Students work together to perform tasks such as examining quantitative relations between physical quantities in a science article, and communicating experimental findings through written reports, posters or oral presentations. Teachers provide opportunities for students to work collaboratively with them to build up knowledge and skills.

These three learning and teaching approaches can be represented as a continuum along which the roles of teachers and students vary. For instance, as illustrated in Figure 4.1, a teacher is more of a resource person than a transmitter of knowledge in a learning co-construction process.

Direct instruction	Interactive teaching	Individualisation	Inquiry	Co-construction
• Demonstration • Explanation • Video show	• Questioning • Visits • Using IT and multimedia packages • Whole-class discussion	• Constructing concept maps • Information searching • Reading • Writing learning journals/ note-taking	• Practical work • Problem-solving • Scientific investigations • Simulation and modelling	• Debates • Discussion forums • Group discussion • Project work • Role-play

Figure 4.1 Learning and Teaching Activities in Physics

A wide variety of approaches and strategies should be adopted to meet the specific learning objectives of individual lessons and the needs and learning styles of students. Teachers should note that a learning target may be attained by using more than one type of strategy and multiple learning targets can be achieved during the same learning process.

4.3.2 Variety and Flexibility in Learning and Teaching Activities

This curriculum has an in-built flexibility to cater for the interests, abilities and needs of students. This flexibility in the design of the expected learning targets serves as a way for teachers to strike a balance between the quality and quantity of learning. Teachers should provide ample opportunities for students to engage in a variety of learning activities to attain different learning targets. Learning and teaching activities such as questioning, reading, discussions, model-making, demonstrations, practical work, field studies, investigations, oral reporting, assignments, debates, information search and role-play are commonly used. For some learning targets, the activities can be selected to suit students' different learning styles.

The learning and teaching activities employed should aim to promote learning for understanding, not the surface learning of unconnected facts. Effective learning is more likely to be achieved when students are active rather than passive, when ideas are discussed and negotiated with others rather than learned alone, and when the content is learned as an integrated whole rather than in small separate pieces. In short, activities that encourage meaningful learning should be used as far as possible.

4.3.3 From Curriculum to Pedagogy: How to start

Teachers have to make informed decisions about the approaches and activities which are most appropriate for achieving specific learning targets. Guidelines on this have been suggested in Section 4.2 for teachers' reference. In the learning of physics, where possible, activities should be made relevant to daily life, so that students will experience physics as interesting, relevant and important to them.

The success of learning and teaching activities depends to a large extent on whether or not the intended learning objectives are met. Some useful learning and teaching strategies in physics are suggested below. However, teachers should note that the suggestions made here are by no means the only approaches/strategies for teaching the topics in the examples. The examples given under the different strategies in this chapter aim at illustrating the more significant learning outcomes that can be achieved, but others may of course also be achieved.

(1) Constructing concept maps

Concept maps are visual aids to thinking and discussion. They help students to describe the links between important concepts. They can be used as tools to generate ideas, communicate complex ideas, aid learning by explicitly integrating new and old knowledge and assess understanding or diagnose misconceptions. Students should be encouraged to construct concept maps of their understanding of a topic, and subsequently refine them in the light of teachers' comments, peer review and self-evaluation in the course of learning. To familiarise students with this way of representing information, they may first be asked to add the links between concepts or label the links on a partially prepared concept map. Apart from drawing them by hand, a wide range of computer programs for concept mapping are available which enable users to create and revise concept maps easily.

Example

Students are asked to design a cooker using solar energy. Students first discuss what they already know about the concepts of energy transfer which are related to the design of a solar cooker. The concepts may include the three modes of energy transfer, i.e. radiation, convection and conduction, and ways to gain maximum solar energy by using an effective collecting system for sun rays and minimise energy loss by proper insulation. Then they organise and connect their own concepts into a coherent concept map, as shown in Figure 4.2. This is followed by reflection on the concepts by discussing the concept map with others. Suggestions on the design of the solar cooker and the advantages and disadvantages of solar cooking are gathered after discussion. Finally, completion of the concept map serves to consolidate the relevant concepts learned and extend students' learning on energy transfer.

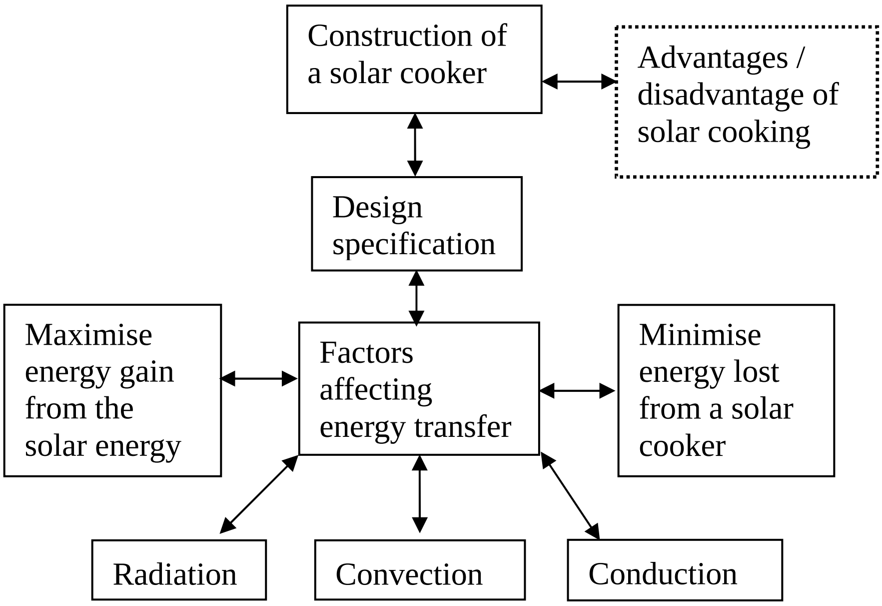

Figure 4.2 Concept Map on designing a Solar Cooker

(2) Searching for and presenting information

Searching for information is an important skill in the information era. Students can gather information from various sources such as books, newspapers, magazines, scientific publications, multimedia, digital media and the Internet. Information can be turned by students into knowledge and can be drawn upon for making informed judgments. Information should not simply be collected selectively by students but must be categorised, analysed and put to some use, for example in a presentation of findings. Teachers may set questions, topics, discussion areas, issues for debate and project titles for students and then encourage them to look for relevant information in the library and on the Internet.

It is desirable for students to have experience of how to work with information in diverse environments, especially with imperfect and vague information from sources that may be doubtful. Students can easily be overwhelmed with information, and so it is very important for them to be guided or to have to learn how to filter information according to their needs.

(3) Reading to learn

Reading to learn can be used to promote independent learning and achieve the objectives of the curriculum. In particular, it can help students to understand various aspects of the past, present and possible future development of physics.

Students should be given opportunities to read physics articles of appropriate breadth and depth independently. This will develop their ability to read, interpret, analyse and communicate new scientific concepts and ideas. Meaningful discussions on good physics articles among students and with teachers may be used both to co-construct knowledge and to strengthen students' general communication skills. Development of the capacity for self-directed learning will be invaluable in preparing students to become active lifelong learners.

Articles which emphasise the interconnections among science, technology, society and the environment can reinforce and enrich the curriculum by bringing in current developments and relevant issues, and so arouse students' interest in learning. Teachers should select articles suited to the interests and abilities of their students; and students should be encouraged to search for articles themselves from newspapers, science magazines, the Internet, and library books.

The main purpose of this strategy is to encourage reading for meaning. This can be promoted through a wide variety of after-reading activities such as simple and/or open-ended questions to help students to relate what they have read to their experience, the writing of a summary or short report about an article, the making of a poster, or the creation of a story to stimulate imaginative thinking. They should also be encouraged to share what they have read with their classmates in order to cultivate the habit of reading physics articles.

Example

In topic VII "Atomic World", it is suggested that students should read articles on the development of atomic physics in the twentieth century (e.g. the article on "How physicists study the structure of matter?" in the website "Enhancing Science Learning through Electronic Library" http://resources.edb.gov.hk/physics). Knowing about the historical advances in physics provides students with a better understanding of the nature of science. The stories of famous physicists always motivate students to appreciate the ways they approached a problem, the work they did and the joy and frustration they experienced. This activity not only helps students to understand the major trends in the development of atomic physics, but also to appreciate the efforts of physicists in searching for the ultimate structure of matter (e.g. man-made carbon nano tubes and their applications). It also helps teachers to assess what their students have learned after reading, through activities such as presentations, discussion, questions and summaries.

(4) Discussion

Questioning and discussion in the classroom promote students' understanding, and help them to develop higher-order thinking skills and an active approach to learning. Also, presenting arguments enables them to develop the following skills: extracting useful information from a variety of sources; organising and presenting ideas in a clear and logical way; and making judgments based on valid arguments.

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

One of the effective ways to motivate students is to make discussion and debate relevant to their everyday lives. For example, in topic V, the use of nuclear power is an interesting subject for discussion. It increases students' awareness of effective ways to match the high demand for energy use nowadays, with its potential hazards to our bodies and the environment.

More student-centred strategies can be adopted in addressing issues related to science, technology, society and the environment. For example, in topic VIII, environmental issues related to the use of different energy sources are discussed. Teachers can start by raising the issues of energy efficiency, energy auditing in schools and being a smart energy consumer. In the discussion, students should be free to express their opinions, and then suggest methods for saving energy and reducing pollution, and the difficulties of putting these into practice. Lastly, students can present their ideas to the whole class for their classmates and the teacher to comment on.

(5) Practical work

As Physics is a practical subject, it is essential for students to gain personal experience of science through activities involving doing and finding out. In the curriculum, designing and performing experiments are given due emphasis. Students should also come to be aware of the importance of being careful and accurate when doing practical work and handling measurements.

As students develop their practical skills, teachers can gradually provide less and less guidance. Inquiry-based experiments are recommended to promote independent learning. In an inquiry-based approach, students have to design all or part of the experimental procedures, decide on what data to record, and to analyse and interpret the data. In this process, students will show more curiosity and a greater sense of responsibility in their own experiments, leading to significant gains in their development of science process skills.

Moreover, it is better to design experiments to "find out" rather than to "verify". Teachers should avoid telling students the results before they engage in practical work, and students should try to draw their own conclusions from the experiments. Gradually students will be guided towards independent scientific investigation. The following figure illustrates how students build up their knowledge of scientific principles and skills through practical work.

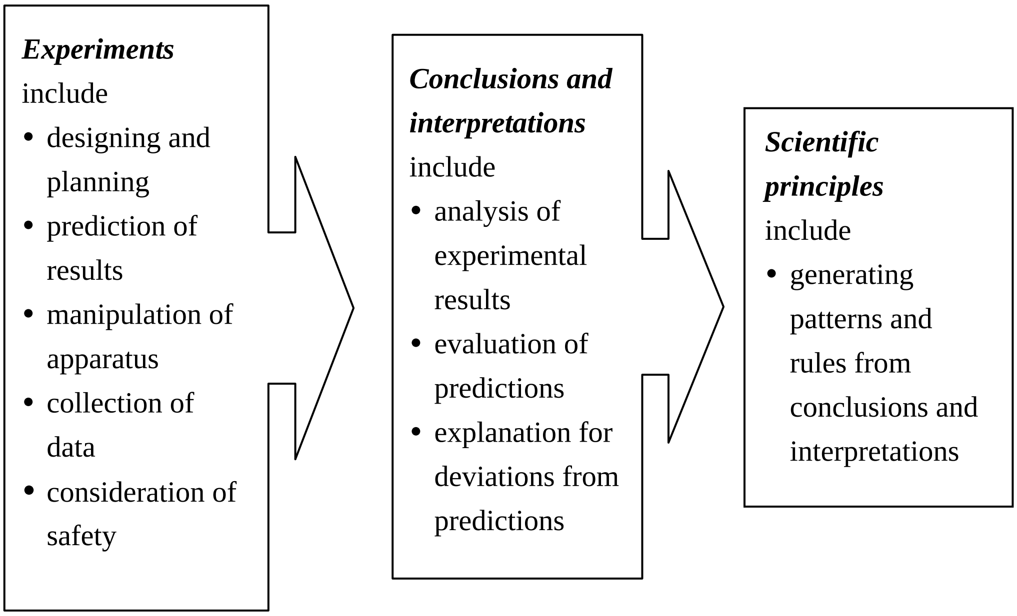

Figure 4.3 The Development of Understanding of Scientific Principles and Skills through Practical Work

(6) Investigative Study

Investigative Study, which is a powerful strategy for promoting self-directed learning and reflection, enables students to connect knowledge, skills and values and attitudes through a variety of learning experiences. In the Investigative Study of this curriculum, students work in small groups to plan, collect information and make decisions. This develops a variety of skills such as scientific problem-solving, critical thinking, communication and collaboration skills, practical skills and important science process skills.

Short and simple investigations can be arranged, preferably from an early stage in the curriculum, to develop the skills required for the Investigative Study. As there are many ways to collect scientific evidence, it is desirable to expose students to different types of investigation (e.g. a solar cooker, the speed of sound, energy audits or plotting an electric field). By so doing, students will progress from "cook-book" type experiments to more open-ended investigations which involve finding answers to the questions they have formulated themselves.

> *Example*
> A short investigation, a "solar cooker competition", can be organised after covering the topics in "Transfer processes". Students are expected to apply their physics knowledge of conduction, convection and radiation, and skills acquired in previous topics, to design and conduct a short investigation on energy transfer in constructing a solar cooker. Students can investigate the effects of different materials and designs on the temperature in the cooker. Students can be given about two 40-minute periods for planning the investigation, for example, one period for drafting a brief plan in small groups and one period for whole-class discussion. They can form working groups to construct the solar cookers after school, followed by two to three periods for them to conduct temperature measurements of cookers under direct sun rays. They can be asked to discuss and make an appropriate choice of temperature-measuring instruments before the experiment. A more in-depth version of the investigation could require students to determine the power rating of the designed solar cooker and relate it to the solar constant obtained from the literature.

In general, the activities in Investigative Study involve several levels of inquiry, depending on students' skills and needs, and the amount of information given to them. They can be broadly categorised into four levels. For instance, in level one, students are provided with a problem to be investigated with prescribed procedures and the expected results known in advance. Students need to verify the results according to the procedures given. In level two, students investigate a problem set by the teacher through a prescribed procedure but the results are unknown to them. In level three, students investigate a teacher-set question using procedures which they design or select by themselves. Finally, in level four, both the problem and investigative methods are formulated and designed by students. This four-level model also shows how the investigative nature of the activities may vary from highly teacher-directed to highly student-centred. The model allows teachers to tailor the Investigative Study to the level of readiness of the class.

(7) Problem-based learning

Problem-based learning (PBL) is an instructional method driven by a problem. PBL is most commonly used in professional courses where students are given authentic problems of the kind they will face at work, but it is being used increasingly in many disciplines. The problems are open-ended, often based on real-life situations and ill-defined with no quick and easy solutions. In PBL, the problem may not involve prior presentation of subject matter. In the process of investigating and solving the problem, students may acquire new knowledge and integrate it with what they have learned in the curriculum. Students are required to work in groups to: understand and define the problem; discover and learn what they need to know in order to tackle it; generate alternatives; develop and test solutions; and justify their suggested solutions. Teachers assume the role of facilitators, resource persons and observers of students' contributions and participation. Students are motivated by actively engaging in the learning process and taking responsibility for their own learning.

Apart from motivating students to develop a deeper subject understanding, PBL encourages them to think scientifically, critically and creatively, and to solve problems collaboratively in physics-related contexts. Many topics in the curriculum offer rich contexts for PBL. Also, problems with different levels of complexity can be given to students, with hints or thought-provoking questions to guide their analysis, if necessary.

Example

You are a manager of a restaurant. The senior management and the owners of your restaurant, who are always looking for ways of reducing costs, initiate a change to flameless cooking in your restaurant. You are asked to lead a working group to study the feasibility of this change.

The following questions can be raised to help students to analyse the problem:

- What is flameless cooking and what is induction cooking?
- What are the principles of induction cooking?
- Why can induction cooking be more efficient in saving energy than traditional cooking?
- What are the possible savings per month?
- What will be the possible cost of investment and when will the restaurant reach the break-even period?
- Any other options?
- Any other considerations?

(Information from http://www.cuhk.edu.hk/sci/case-learning)

(8) Context-based learning

Learning is most effective if it is built upon the existing knowledge of students. Learning through a real-life context accessible to students will increase their interest and enhance the learning of physics. Context-based learning highlights the relevance of physics to students' daily lives and can be employed to enhance their awareness of the interconnections among science, technology, society and the environment. When students have learned the original concepts effectively and confidently, they can transfer their concepts, knowledge and skills to other contexts. Teachers are strongly encouraged to adopt a contextual approach in implementing the curriculum.

Different approaches need to be used at different stages of learning. Within any one stage, there can be many other strategies and examples which are just as effective. The rationale behind context-based learning lies in integrating theory with real-life experience. However, since this depends on the particular group of students, time and place, a range of teaching strategies may need to be adopted for this approach to be successful.

Example

Modern cars have crumple zones which crumple easily in collisions, thus helping to protect the passengers in a car accident. In this activity, students are asked to design and build a crumple zone for a toy car, and then to test their design using a data logger. They are encouraged to design their own tests and justify their choices. Information in the web page Contextual Physics (http://www.hk-phy.org/contextual/) is a helpful resource for students in conducting this activity.

(9) Information technology (IT) for interactive learning

IT is a valuable tool for interactive learning both inside and outside the classroom. IT often provides an interactive environment for learners to take control of the organisation and content of their own learning. With the appropriate use of IT-mediated resources, teachers can enhance students' understanding of physics concepts and processes, and develop their IT skills which are useful for lifelong learning.

There are numerous and growing opportunities to use IT to improve, but not to replace, the learning experience in physics. In Physics in particular, the use of IT can extend and enhance learning and teaching in many ways. The following are some examples:

- Computer images can be used to illustrate the shape of the internal structures of an ear, the functions of different parts of a nuclear reactor and the 3-D shape of simple covalent molecules. These computer images can be manipulated as if one was examining a real model.
- Animations can help students to visualise abstract physics concepts and processes (e.g. the formation of stationary waves).

- Digitised videos are particularly useful for students to analyse the motion of a moving object. Any moving object captured appropriately in a video clip can be analysed using the Motion Video Analysis (MVA) software developed by the EDB. The software provides built-in data analysis features such as motion graph plotting and curve fitting functions. Motions varying from the movement of a dolphin jumping out of water to the launching of a rocket into space can be analysed using this MVA software. (The MVA software can be downloaded from http://www.hk-phy.org /oceanpark/index.html)
- Computer simulations can be used to model, for example, equations of motion, the factors affecting the path of a projectile and the processes of a nuclear power plant. Students can carry out a number of virtual experiments safely and quickly to discover the relationships between different variables of a physical system. They can learn from their mistakes without paying the price of real errors. (The software “Modellus” can be used freely for any educational purpose: http://modellus.fct.unl.pt/)
- Spreadsheet programs can be used in analysing and plotting experimental data. They can also be used in the modelling of physical systems such as radioactive decay, thus allowing students to explore “what-if” situations. This can move students’ understanding beyond repetitive calculations and the plotting of numerical results.
- Data loggers and sensors are particularly useful for experiments which involve very rapidly changing data, are very lengthy or have to capture multiple sets of data simultaneously. For instance, they can be used to study the variation of the force during a collision. The software accompanying a data logger can generate various graphical representations of the data immediately so that students can have more time to analyse, discuss and evaluate experimental results after runs.
- The Internet allows students to go beyond textbooks to find current and authentic information to help them to understand concepts, acquire knowledge, and observe and explore the world outside school.
- Synchronous and asynchronous communication tools and web-based collaborative knowledge-building platforms such as Knowledge Forum and CMapTools can facilitate interactivity and dialogue among students, and therefore encourage sharing and active construction of knowledge. More knowledgeable participants can act as teachers as well learners.
- Online assessment tools can provide instant feedback to teachers and students. The functions for tracking the answers of individual students can give teachers information on students’ understanding of concepts which may help them to identify student misconceptions and learning difficulties.
- Interactive computer-aided learning resources can enhance the active participation of students in the learning process. Internet access is widespread, and so students can easily get access to web-based learning resource anywhere and at any time.

(10) Providing life-wide learning opportunities

As learning can take place anywhere, not just in the classroom or school environment, it is essential to provide out-of-school learning experiences for students. Life-wide learning opportunities can widen students' exposure to the real scientific world. Examples of appropriate learning programmes include popular science lectures, debates and forums, field studies, museum visits, invention activities, science competitions, science projects and science exhibitions. These programmes can also offer challenging learning opportunities for students with outstanding ability or a strong interest in science. For example, students can use the Ocean Park Hong Kong as a large laboratory to investigate the laws of motion and develop numerous concepts in mechanics from a variety of experiences at the park (http://www.hk-phy.org/oceanpark/index.html). These programmes can extend students' science capabilities and allow them to develop their full potential. The STSE connections described in Chapter 2 are a good reference for organising life-wide learning opportunities.

4.4 Interaction

Interaction, with feedback on students' performance or responses, is very important for successful learning, and is integral to many learning and teaching strategies. It involves communication among students as well as between teachers and students. Lessons should be planned to ensure that the interaction which takes place is meaningful.

4.4.1 Scaffolding Learning

To develop the understanding and acquire the skills described in Chapter 2, students have to be provided with sufficient support and appropriate scaffolding of their learning from time to time. Scaffolding can take many forms, including:

- Relevant resource materials – for example, an article on the use of non-ionizing radiation in medical imaging and photographs of a body tissue in a B-scan image, to help students to understand how medical diagnosis benefits from advances in physics;
- Guidelines and templates – for instance, a worksheet with guiding questions to help students in planning their own experiments;
- Teacher debriefings – for example, the presentation of a clear conceptual framework at the end of an activity to help students who have difficulty in conceptualising the essence of the activity, or who encounter obstacles that significantly hinder their learning.

The use of scaffolds helps students to learn by making sense of concepts and building knowledge individually or collaboratively. Interaction is itself a useful scaffold to guide students along as they undertake activities.

4.4.2 Effective Feedback

Teachers should provide specific, frequent and prompt feedback which reinforces students' achievements and provides them with a clear direction for further study of the topic concerned, until the related learning target is achieved. This experience will increase students' mastery of the necessary knowledge and skills for further study, and encourage them to be more confident in self-directed learning.

Example

In teaching the topic "acceleration due to gravity", for example, teachers can challenge students by asking a series of guiding questions about the results observed from the "feather and guinea" experiment. Based on students' responses, intervention through feedback may be made. Students can be asked to compare the motion of the feather and guinea with two falling objects of different masses; and as a further investigation, they may be required to find out the numerical value of acceleration due to gravity. This can strengthen students' ability to describe the physical phenomena in a quantitative manner. During the experiment, different groups of students may raise various questions about, for instance, the use of apparatus and ways to obtain a more accurate result, to which teachers can provide feedback. Students can also learn from peers in their groups, sometimes supported by the teacher. After getting the experimental results, teachers can provide feedback to guide the students to find out the sources of any errors and, if necessary, the means to verify whether or not the assumptions about error sources are valid according to the learning objectives set.

Depending on the learning target, and students' ability and interest in this topic, a further investigation can be arranged to reinforce the learning of the concept of acceleration due to gravity by, for example, estimating the time of a free falling object from a high-rise building. Extra practical activities may also be arranged on, for instance, the measurement of contact time during a collision and an analysis of an actual accident involving an object falling from a high-rise building. It should be noted that the use of activities for further investigation is a result of interaction between the teacher and students, with feedback on students' performance.

For effective interaction between teachers and students, and among students, teaching activities need to be well prepared. Teachers need to know when and how to intervene and provide appropriate feedback. Due consideration should be also given to the support needed to enhance and sustain students' learning. The support can take the form of, for example, a set of organised guiding questions for solving a problem or systematic procedures for conducting a learning task. Meanwhile, time should be made available for students' own explorations. Resources such as laboratory and IT facilities are also helpful to facilitate students' exploration in this regard.

4.4.3 Use of Interaction for Assessment

Interaction with appropriate feedback can facilitate formative assessment to promote learning. During the interaction process, both teachers and students can assess how well students understand the theories or concepts concerned. Classroom-based continuous assessment tasks are good tools for helping students to manage and regulate their learning. To be effective, formative assessment should consist of prompt feedback which goes well beyond the mere provision of marks to include, for example, oral or written comments on students' strengths and weaknesses in learning, and suggestions on areas for improvement. In this way, students are helped to understand learning targets and recognise how they can learn better.

4.5 Catering for Learner Diversity

4.5.1 Knowing our Students

Our students vary widely in ability and needs, so it is unrealistic to expect them all to achieve the same level of attainment. In catering for such diversity, we first need to know our students. It is imperative for teachers to identify the "building blocks" of learning and systematically make them available to students in manageable chunks that do not exceed their capacities.

For the less able students, more guidance and patience from teachers is required; while able students benefit greatly from independence and more enrichment in learning. The overall aim is to motivate learning by making the path enjoyable and challenging, and within students' reach.

4.5.2 Flexible Grouping

Learner diversity can be viewed as an opportunity to get students to provide mutual support, especially when they work collaboratively to complete a learning task. This is particularly relevant for Hong Kong students, who often rely on support from their peers and are receptive to cooperation in learning. Students of differing abilities can be grouped together so that the more and less able ones can share their knowledge. Alternatively, students with similar ability can be grouped together to work on tasks with similar degrees of appropriate challenge so that a sense of success and confidence in learning is created.

4.5.3 Matching Teaching with Learning Abilities

Using a range of teaching strategies and matching them to students' learning abilities can improve learning significantly. For academically low achievers, teachers should carefully anticipate the difficulties students might encounter and offer step-by-step specific instruction prompts. For students who are outstanding and academically ready for challenges, teachers might need to provide challenges which have clear learning outcomes.

Example

In tackling the topic II(c) "projectile motion", a direct instruction or an inquiry approach could be adopted. Similar teaching materials but with different strategies can cater for students with different levels of academic ability. In direct instruction, teachers may demonstrate projectile motions with different inclined angles to start the topic. After discussing with students the independence of horizontal and vertical motions, teachers can derive equations relating different physical quantities such as time of flight, range and maximum height; and perform the "monkey and hunter" experiment to consolidate the concepts taught.

In an inquiry approach, students can be asked to conduct the "monkey and hunter" experiment in small groups as a stimulus. By analysing the motion of the bullet compared with that of the monkey, students are guided to focus on the independence of horizontal and vertical motions, and hence to construct the relationship between physical quantities such as time of flight, range and maximum height. Students can conduct experiments on projectile motion with different inclined angles to verify their findings. Also, investigative activities on projectile motions in daily life can be introduced for students who are interested in this topic.

4.5.4 Catering for the Gifted Students

The needs of students with special gifts or talents in physics should be catered for. Schools should help them to develop their potential to the fullest. One way of achieving this is through acceleration. That means allowing gifted students to move quickly through particular courses, for example, the Physics Olympiad program, while keeping them with their peers for most classes. Another approach is through enrichment. This means involving gifted students in additional sophisticated or thought-provoking work, while keeping them with their age-mates in school. Such students should be given more challenging scientific inquiry activities. They should also be encouraged to act independently, for example, in defining problems, using a range of information sources and evaluating procedures so that they can then regulate their learning by exploring their own personal interests in the learning of physics. For instance, in conducting the Investigative Study, they can be allowed to choose their own topic freely and set challenging objectives for their investigations according to their personal interests and abilities.

4.5.5 Better Use of IT Resources

If used appropriately, IT can be very effective in catering for students' varied learning styles, and can be used for expanding learning beyond the classroom. For example, multimedia programs, such as virtual experiments and simulation programs, can be motivating, especially for students who prefer visual approaches to learning. IT is particularly valuable for learning about physics phenomena which cannot be easily observed in daily life, and require abstract thinking or special equipment. Students can also use animation programmes to control and adjust different parameters and explore the consequences; and they can carry out experiments at a pace which suits their ability and attainment. Finally, the use of Motion Video Analysis (MVA) and data logger equipment extends the possibilities for practical work in learning physics. Teachers can also make use of communication programmes such as newsgroups and on-line assessment tools to provide instant and interactive feedback to students with different learning styles and aptitudes.

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Chapter 5 Assessment

This chapter discusses the role of assessment in Physics learning and teaching, the principles that should guide assessment of the subject and the need for both formative and summative assessment. It also provides guidance on internal assessment and details regarding the public assessment of Physics. Finally, information is given on how standards are established and maintained, and how results are reported with reference to these standards. General guidance on assessment can be found in the *Senior Secondary Curriculum Guide* (SSCG) (CDC, 2009).

5.1 The Roles of Assessment

Assessment is the practice of collecting evidence of student learning. It is a vital and integral part of classroom instruction, and serves several purposes and audiences.

First and foremost, it gives feedback to students, teachers, schools and parents on the effectiveness of teaching and on students' strengths and weaknesses in learning.

Second, it provides information to schools, school systems, government, tertiary institutions and employers to enable them to monitor standards and to facilitate selection decisions.

The most important role of assessment is in promoting learning and monitoring students' progress. However, in the senior secondary years, the more public roles of assessment for certification and selection come to the fore. Inevitably, these imply high-stakes uses of assessment since the results are typically employed to make critical decisions about individuals.

The HKDSE provides a common end-of-school credential that gives access to university study, work and further education and training. It summarises student performance in the four core subjects and in various elective subjects, including both discipline-oriented subjects such as Physics and the new Applied Learning (ApL) courses. It needs to be read in conjunction with other information about students given in the Student Learning Profile.

5.2 Formative and Summative Assessment

It is useful to distinguish between the two main purposes of assessment, namely "assessment *for* learning" and "assessment *of* learning".

"Assessment *for* learning" is concerned with obtaining feedback on learning and teaching, and utilising this to make learning more effective and to introduce any necessary changes to teaching strategies. We refer to this kind of assessment as "formative assessment" because it is all about forming or shaping learning and teaching. Formative assessment is something that should take place on a daily basis and typically involves close attention to small "chunks" of learning.

"Assessment *of* learning" is concerned with determining progress in learning, and is referred to as "summative assessment" because it is all about summarising how much learning has taken place. Summative assessment is normally undertaken at the conclusion of a significant period of instruction (e.g. the end of the year, or at the end of a key stage of schooling) and reviews much larger "chunks" of learning.

In practice, a sharp distinction between formative and summative assessment cannot always be made, because the same assessment can in some circumstances serve both formative and summative purposes. Teachers can refer to the *Senior Secondary Curriculum Guide* (CDC, 2009) for further discussion of formative and summative assessment.

Formative assessment should also be distinguished from continuous assessment. The former refers to the provision of feedback to improve learning and teaching based on formal or informal assessment of student performance, while the latter refers to the assessment of students' ongoing work, and may involve no provision of feedback that helps to promote better learning and teaching. For example, accumulating results in class tests carried out on a weekly basis, without giving students constructive feedback, may neither be effective formative assessment nor meaningful summative assessment.

There are good educational reasons why formative assessment should be given more attention and accorded a higher status than summative assessment, on which schools tended to place greater emphasis in the past. There is research evidence on the beneficial effects of formative assessment, when used for refining instructional decision-making in teaching and generating feedback to improve learning. For this reason, the CDC Report *Learning to Learn – The Way Forward in Curriculum Development* (CDC, 2001) recommended that there should be a change in assessment practices, with schools placing due emphasis on formative assessment to make assessment *for* learning an integral part of classroom instruction.

It is recognised, however, that the primary purpose of public assessment, which includes both public examinations and moderated school-based assessments (SBA), is to provide summative assessments of the learning of each student. While it is desirable that students are exposed to SBA tasks in a low-stakes context and benefit from practice and experience with such tasks (i.e. for formative assessment purposes) without penalty, similar tasks will need to be administered subsequently as part of the public assessment to generate marks to summarise the learning of students (i.e. for summative assessment purposes).

Another distinction to be made is between internal assessment and public assessment. Internal assessment refers to the assessment practices that teachers and schools employ as part of the ongoing learning and teaching process during the three years of senior secondary studies. In contrast, public assessment refers to the assessment conducted as part of the assessment process in place for all schools. Within the context of the HKDSE, this means both the public examinations and the moderated SBA conducted or supervised by the HKEAA. On balance, internal assessment should be more formative, whereas public assessment tends to be more summative. Nevertheless, this need not be seen as a simple dichotomy. The inclusion of SBA in public assessment is an attempt to enhance formative assessment or assessment *for* learning within the context of the HKDSE.

5.3 Assessment Objectives

The assessment objectives are closely aligned with the curriculum framework and the broad learning outcomes presented in earlier chapters.

The learning objectives to be assessed in Physics are listed below:

- recall and show understanding of the facts, concepts, models and principles of physics, and the relationships between different topic areas in the curriculum framework;
- apply knowledge, concepts and principles of physics to explain phenomena and observations, and to solve problems;
- demonstrate understanding of the use of apparatus in performing experiments;
- demonstrate understanding of the methods used in the study of physics;
- present data in various forms, such as tables, graphs, charts, diagrams, and transpose them from one form into another;
- analyse and interpret data, and draw conclusions from them;
- show understanding of the treatment of errors;

- select, organise, and communicate scientific information clearly, precisely and logically;
- show understanding of the applications of physics to daily life and the contributions of physics to the modern world;
- show awareness of the ethical, moral, social, economic and technological implications of physics, and critically evaluate physics-related issues; and
- make decisions based on the examination of evidence using knowledge and principles of physics.

5.4 Internal Assessment

This section presents the guiding principles that can be used as the bases for designing internal assessment and some common assessment practices for Physics for use in schools. Some of the guiding principles are common to both internal and public assessment.

5.4.1 Guiding Principles

Internal assessment practices should be aligned with curriculum planning, teaching progression, student abilities and local school contexts. The information collected will help to motivate, promote and monitor student learning, and will also help teachers to find ways of promoting more effective learning and teaching.

(1) Alignment with the learning objectives

A range of assessment practices should be used to assess comprehensively the achievement of different learning objectives including knowledge and understanding of the principles and concepts of physics, scientific skills and processes, and positive values and attitudes. The weighting given to different areas in assessment should be discussed and agreed among teachers. The assessment purposes and assessment criteria should also be made known to students so that they can have a full understanding of the learning to be achieved.

(2) Catering for the range of student ability

Assessment at different levels of difficulty and in diverse modes should be used to cater for students with different aptitudes and abilities. This helps to ensure that the more able students are challenged to develop their full potential, and the less able ones are encouraged to sustain their interest and success in learning.

(3) Tracking progress over time

As internal assessment should not be a one-off exercise, schools are encouraged to use practices that can track learning progress over time (e.g. portfolios). Assessment practices of this kind allow students to set their own incremental targets and manage their own pace of learning, which will have a positive impact on their commitment to learning.

(4) Timely and encouraging feedback

Teachers should provide timely and encouraging feedback through a variety of means, such as constructive verbal comments during classroom activities and written remarks on assignments. Such feedback helps students to sustain their momentum in learning, and to identify their strengths and weaknesses.

(5) Making reference to the school's context

As learning is more meaningful when the content or process is linked to a setting which is familiar to students, schools are encouraged to design assessment tasks that make reference to the school's own context (e.g. its location, relationship with the community and mission).

(6) Making reference to the current progress in student learning

Internal assessment tasks should be designed with reference to students' current progress in learning, as this helps to overcome obstacles that may have a cumulative negative impact on learning. Teachers should be mindful in particular of concepts and skills which form the basis for further development in learning.

(7) Feedback from peers and from the students themselves

In addition to giving feedback, teachers should also provide opportunities for peer assessment and self-assessment in student learning. The former enables students to learn among themselves, and the latter promotes reflective thinking which is vital for students' lifelong learning.

(8) Appropriate use of assessment information to provide feedback

Internal assessment provides a rich source of data for providing evidence-based feedback on learning in a formative manner.

5.4.2 Internal Assessment Practices

A range of assessment practices suited to Physics, such as assignments, practical work and scientific investigations, oral questioning, should be used to promote the attainment of the various learning outcomes. However, teachers should note that these practices should be an integral part of learning and teaching, not "add-on" activities.

(1) Assignments

Assignments are a valuable and widely used assessment tool that reflects students' efforts, achievements, strengths and weaknesses over time. A variety of assignment tasks – such as exercises, essays, designing posters or leaflets, and model construction – can be used to allow students to demonstrate their understanding and creative ideas. The assignment tasks should be aligned with the learning objectives, teaching strategies and learning activities. Teachers can ask students to select a topic of interest, search for information, summarise their findings and devise their own ways of presenting their work (e.g. role-play, essays, poster designs or PowerPoint slides). Teachers should pay close attention to students' organisation of the materials, the language they use, the breadth and depth of their treatment, and the clarity with which they explain concepts. The scores or grades for assignments can be used as part of the record of students' progress; and the comments on their work, with suggestions for improvement, provide valuable feedback to them. Assignments can also help in evaluating the effectiveness of teaching by providing feedback upon which teachers can set further operational targets for students and make reasonable adjustments to their teaching strategies.

(2) Practical work and scientific investigation

Practical work and scientific investigation are common activities in the learning and teaching of science subjects. They offer students "hands-on" experience of exploring, and opportunities to show their interest, ingenuity and perseverance. In scientific investigations, teachers can first pose a problem and ask students to devise a plan and suggest appropriate experimental procedures for solving it – and the design of the investigations can then be discussed and, if necessary, modified. During such sessions, teachers can observe students' practical skills and provide feedback on how the experiment/investigation might be improved. Reading students' laboratory reports can provide teachers with a good picture of students' understanding of the concepts and principles of physics involved, as well as their ability to handle and interpret data obtained in investigations.

(3) Oral questioning

Oral questioning can provide teachers with specific information on how students think in certain situations, as their responses often provide clues to their level of understanding, attitudes and abilities. Teachers can use a wide range of questions, from those which involve fact-finding, problem-posing, and reason-seeking to more demanding ones which promote higher levels of thinking and allow for a variety of acceptable responses. This can be a valuable supplement to conventional assessment methods.

5.5 Public Assessment

5.5.1 Guiding Principles

(1) Alignment with the curriculum

The outcomes that are assessed and examined through the HKDSE should be aligned with the aims, learning targets and intended learning outcomes of the senior secondary curriculum. To enhance the validity of the public assessment, the assessment procedures should address the range of valued learning outcomes, and not just those that are assessable through external written examinations.

The public assessment for Physics places emphasis on testing candidates' ability to apply and integrate knowledge in authentic and novel situations. In addition, the SBA component extends the public assessment to include scientific investigative skills and generic skills.

(2) Fairness, objectivity and reliability

Students should be assessed in ways that are fair and are not biased against particular groups of students. A characteristic of fair assessment is that it is objective and under the control of an independent examining authority that is impartial and open to public scrutiny. Fairness also implies that assessments provide a reliable measure of each student's performance in a given subject so that, if they were to be repeated, very similar results would be obtained.

(3) Inclusiveness

The assessments and examinations in the HKDSE need to accommodate the full spectrum of student aptitudes and abilities.

The public examination for Physics contains questions testing candidates' knowledge of the foundations and selected areas in physics, and test higher-order thinking skills. At the same time, the SBA component offers room for a wide range of practical activities to cater for the different preferences and readiness among students and/or schools.

(4) Standards-referencing

The reporting system is "standards-referenced", i.e. student performance is matched against standards, which indicate what students have to know and be able to do to merit a certain level of performance. Level descriptors have been developed for Physics to provide information about the typical performance of candidates at the different levels.

(5) Informativeness

The HKDSE qualification and the associated assessment and examinations system provide useful information to all parties. First, it provides feedback to students on their performance and to teachers and schools on the quality of the instruction provided. Second, it communicates to parents, tertiary institutions, employers and the public at large what it is that students know and are able to do, in terms of how their performance matches the standards. Third, it facilitates selection decisions that are fair and defensible.

5.5.2 Assessment Design

The table below shows the assessment design of Physics with effect from the 2016 HKDSE Examination. The assessment design is subject to continual refinement in the light of feedback from live examinations. Full details are provided in the Regulations and Assessment Frameworks for the year of the examination and other supplementary documents, which are available on the HKEAA website (www.hkeaa.edu.hk/en/hkdse/assessment/assessment_framework/).

<table>
<tr><th colspan="2">Component</th><th>Weighting</th><th>Duration</th></tr>
<tr><td rowspan="2">Public Examination</td><td>Paper 1 Compulsory Part</td><td>60%</td><td>2½ hours</td></tr>
<tr><td>Paper 2 Elective Part
(a choice of two out of four elective topics)</td><td>20%</td><td>1 hour</td></tr>
<tr><td colspan="2">School-based assessment (SBA)</td><td>20%</td><td></td></tr>
</table>

5.5.3 Public Examinations

The overall aim of the public examination is to assess candidates' ability to demonstrate their knowledge and understanding in different areas of physics, and to apply this to familiar and unfamiliar situations.

Various kinds of items, including multiple-choice questions, short questions, structured questions and essays, are used to assess students' performance in a broad range of skills and abilities. Multiple-choice questions permit a more comprehensive coverage of the curriculum, while basic knowledge and concepts can be tested through short questions. In structured questions, candidates may be required to analyse given information and to apply their knowledge to different situations. Finally, essay questions allow candidates to discuss issues in physics in depth and demonstrate their ability to organise and communicate ideas logically and coherently. Schools may refer to the live examination papers regarding the format of the examination and the standards at which the questions are pitched.

5.5.4 School-based Assessment (SBA)

In the context of public assessment, SBA refers to assessments administered in schools and marked by the students' own teachers. The primary rationale for SBA in Physics is to enhance the validity of the assessment by including the assessment of students' practical skills and generic skills.

There are, however, some additional reasons for SBA. For example, it reduces dependence on the results of public examinations, which may not always provide the most reliable indication of the actual abilities of candidates. Obtaining assessments based on student performance over an extended period of time and developed by those who know the students best – their subject teachers – provides a more *reliable* assessment of each student.

Another reason for including SBA is to promote a *positive "backwash effect" on students, teachers and school staff*. Within Physics, SBA can serve to motivate students by requiring them to engage in meaningful activities; and for teachers, it can reinforce curriculum intentions and good teaching practice, and provide structure and significance to an activity they are in any case involved in on a daily basis, namely assessing their own students.

The SBA of Physics covers the assessment of students' performances in practical work in their S5 and S6 years of the course. Candidates are required to perform a stipulated amount of practical work, which may include designing experiments, reporting and interpreting experimental results, etc. The work should be integrated closely with the curriculum and form a part of the normal learning and teaching process.

It should be noted that SBA is not an "add-on" element in the curriculum. The modes of SBA above are normal in-class and out-of-class activities suggested in the curriculum. The requirement to implement the SBA has taken into consideration the wide range of abilities of students and efforts have been made to avoid unduly increasing the workload of both teachers and students. Detailed information on the requirements and implementation of the SBA and samples of assessment tasks are provided to teachers by the HKEAA.

5.5.5 Standards and Reporting of Results

Standards-referenced reporting is adopted for the HKDSE. What this means is that candidates' levels of performance are reported with reference to a set of standards as defined by cut scores on mark scale for a given subject. Standards referencing relates to the way in which results are reported and does not involve any changes in how teachers or examiners mark student work. The set of standards for a given subject can be represented diagrammatically as shown in Figure 5.1.

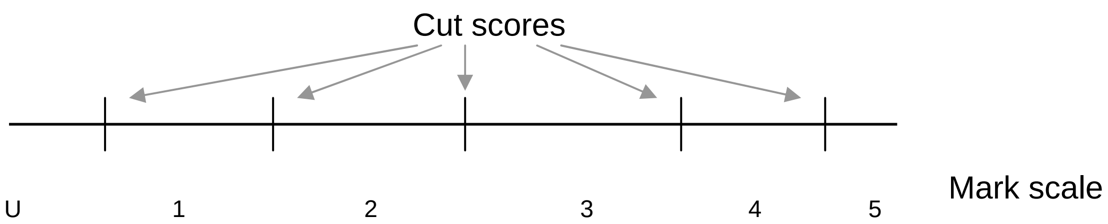

Figure 5.1 Defining Levels of Performance via Cut Scores on the Mark Scale for a given Subject

Within the context of the HKDSE there are five cut scores, which are used to distinguish five levels of performance (1–5), with 5 being the highest. A performance below the cut score for Level 1is labelled as "Unclassified" (U).

For each of the five levels, a set of written descriptors has been developed to describe what the typical candidate performing at this level is able to do. The principle behind these descriptors is that they describe what typical candidate *can* do, not what they *cannot* do. In other words, they will describe performance in positive rather than negative terms. These descriptors represent "on-average" statements and may not apply precisely to individuals, whose performance within a subject may be variable and span two or more levels. Samples of students' work at various levels of attainment are provided to illustrate the standards expected of them. These samples, when used together with the level descriptors, will help to clarify the standards expected at the various levels of attainment.

In setting standards for the HKDSE, Levels 4 and 5 are set with reference to the standards achieved by students awarded grades A–D in the HKALE. It needs to be stressed however, that the intention is that the standards will remain constant over time – not the percentages awarded at different levels, as these are free to vary in line with variations in overall student performance. Referencing Levels 4 and 5 to the standards associated with the old grades A–D is important for ensuring a degree of continuity with past practice, for facilitating tertiary selection and for maintaining international recognition.

The overall level awarded to each candidate is made up of results in both the public examination and the SBA. SBA results for Physics are statistically moderated to adjust for differences among schools in marking standards, while preserving the rank ordering of students as determined by the school.

To provide finer discrimination for selection purposes, the Level 5 candidates with the best performance have their results annotated with the symbols ** and the next top group with the symbol *. The HKDSE Certificate itself record the Level awarded to each candidate.

Chapter 6 Learning and Teaching Resources

This chapter discusses the importance of selecting and making effective use of learning and teaching resources, including textbooks, to enhance student learning. Schools need to select, adapt and, where appropriate, develop the relevant resources to support student learning.

6.1 Purpose and Function of Learning and Teaching Resources

Suitable learning and teaching resources help students to construct knowledge for themselves, and to develop the learning strategies, generic skills, positive values and attitudes they need. Teachers are encouraged to utilise various types of resources in their lessons, and not confine themselves to using textbooks. For example, the Internet not only provides interactive learning opportunities, but also widens students' horizons by keeping them abreast of the latest scientific and technological developments.

School-based learning and teaching materials are also effective resources. They can complement textbooks and cater for students' varied needs. Learning resources that provide students with experiences outside school and support them in developing abstract ideas and concepts are particularly useful. Students can use these resources for independent learning, with teachers' guidance. If used effectively, learning and teaching resources encourage students' personal construction of knowledge and help to lay a solid foundation for lifelong learning.

6.2 Guiding Principles

In order to meet the different objectives of individual lessons and the range of student abilities, teachers need to select a variety of resources for Physics, which should:

- provide specific and appropriate learning targets and directions for learning;
- indicate required prior knowledge to teachers and students;
- provide students with a variety of activities which help them to understand how the content relates to physics concepts and principles;
- guide students' interpretations and reasoning based on evidence;
- provide adequate practice in using physics concepts and principles;
- provide assessment tasks and criteria for reflecting and monitoring student progress; and
- encourage exploration beyond the classroom to support independent and extended learning.

6.3 Types of Resources

6.3.1 Textbooks

Textbooks have a major role to play in helping students to learn concepts and principles of physics and consolidate their learning experiences. However, they should at the same time support student-centred learning and enable students to construct models, theories and understandings for themselves.

Schools should choose physics textbooks that enhance the motivation and learning of students. The following characteristics should be considered when selecting them:

- approach and coverage – whether they support the development of the knowledge, skills, values and attitudes promoted in the curriculum;
- suitability of the content – whether they provide access to knowledge, as well as scaffolding, to help students to make progress in learning physics;
- quality of the language – whether it is unambiguous and accurate;
- appropriateness of the learning activities – whether they arouse students' interest, engage them actively in learning tasks, and promote independent learning;
- use of examples and illustrations – whether the examples and illustrations used are appropriate and promote learning or are distractions; and
- safety aspects of the practical work – whether there are proper precautions and conspicuous warnings about hazards.

A set of guiding principles has been formulated for writing, reviewing and selecting quality textbooks. Teachers are encouraged to refer to these guidelines at http://www.edb.gov.hk/cd when selecting learner-centred textbooks for their students. Also, for schools' reference, a list of recommended textbooks has been compiled and will be updated regularly by the EDB.

6.3.2 Reference Materials

Students should be encouraged to read extensively for better understanding and broadening the scope of their physics learning. It is important to set up a text-rich environment with sufficient curriculum-related materials which are appropriate for students' varied cognitive levels, linguistic competence and interests. Students should be encouraged to get into the habit of reading about physics, to help to kindle a lifelong interest in the subject and its progress. For this purpose, the materials suggested below can be helpful:

(1) Periodicals and journal articles

Information on the latest developments in physics can be found in education and science research journals. These articles usually go beyond simply reporting how to conduct learning and teaching activities by suggesting how they may be integrated into the curriculum and implemented in classrooms. A list of periodicals and journals is given in Appendix 2 for teachers' reference. Teacher librarians may provide assistance to teachers and students in identifying and locating them.

(2) Media resources

There are many interesting print materials produced specially for enriching the learning of physics, e.g. articles on STSE connections, stories about physics knowledge, and advertisements and cartoons in newspapers and science magazines which illustrate intriguing physics phenomena and concepts. Also, issues and problems related to physics and their impact on society are frequently reported in newspapers and TV programmes. Students can collect material on topics of interest such as traffic accidents, ozone depletion, potential hazards due to mobile phones and new physics-related inventions and discoveries. Detailed analysis of these materials can provide valuable learning experiences that extend classroom learning.

6.3.3 The Internet and Technologies

The massive increase in the quantity of information available today has led to the adoption of new approaches to learning and teaching. The strategic use of the Internet and technologies can transform learning and teaching by enhancing student engagement, improving access, and making services more convenient.

The Internet and technologies help in the learning of physics by:

- providing audio-visual aids for understanding difficult concepts;
- providing access to information from a wide range of sources, handling large quantities of information, and extracting valid and useful information;
- allowing students to work at their own pace, including the use of specially designed software packages
- promoting interaction among learners, and between learners and resources/teachers;
- fostering collaboration between learners, and between learners and teachers;
- facilitating the acquisition of information, the development of critical thinking and the building of knowledge, especially with suitable guidance.

Teachers are encouraged to utilise the many useful websites and computer software packages for learning and teaching Physics. For example, they may use interactive animation on a stationary wave to help students to examine the superposition of two waves. Also, an increasing number of websites offer rich sources of relevant information on topical issues such as nanotechnology, medical diagnosis, nuclear energy, radiation protection, environmental protection, renewable energy and energy efficiency.

When used appropriately, technology can provide effective tools for achieving the goals of the Physics Curriculum. It is not necessary to use only high-end products. The technologies can range from VCD players and TVs to tablets and mobile wireless communication systems. The key principle is "fitness for purpose".

6.3.4 Resource Materials developed by the EDB

Resource materials on learning and teaching strategies and "Investigative Study in Physics" will be developed by the EDB to provide ideas for designing appropriate learning and teaching activities for students. When using them, teachers may need to make adjustments according to their students' needs. Some existing resource materials are listed below:

- Motion Video Analysis (MVA) software, materials for contextual physics and articles. These will be updated to meet the requirements of the Physics Curriculum.

- *Safety in Science Laboratories* (EDB, 2013), which is a valuable resource that provides guidelines and information on various aspects of safety in routine laboratory experiments and outdoor or fieldwork activities.

- Experiences from various collaborative research and development projects – such as *Informed Decisions in Science Education*, *Assessment for Learning in Science*, *Infusing Process and Thinking Skills* and *Collaborative Development of Assessment Tasks and Assessment Criteria to Enhance Learning and Teaching in Science Curriculum* are also good sources of information for teachers.

A list of resource materials on learning and teaching Physics published by the EDB is attached in Appendix 3 for teachers' reference. Besides, new resource materials on learning and teaching strategies as well as curriculum emphases will be developed to provide ideas on designing appropriate activities for students. To assist schools in managing curriculum change, the EDB has provided them with a one-stop curriculum resource directory service at www.edb.gov.hk/cr. The directory provides a central pool of ready-to-use learning and teaching resources and useful references developed by the EDB and other parties. Teachers may refer the supplementary notes for teachers for further elaboration of the depth and breadth of the physics curriculum.

6.3.5 Community Resources

Learning physics can be more effective and meaningful when students are able to relate their study to daily-life contexts. Professional and non-government organisations, and government departments, are good sources of support and resources for the learning and teaching of the subject. They can provide opportunities for teacher development in the field and appropriate learning experiences for students. Noted below are some examples of organisations and departments:

- Professional organisations, e.g. the Hong Kong Association for Mathematics and Science Education and the Physical Society of Hong Kong;
- Non-government organisations, e.g. the Hong Kong New Generation Cultural Association and the IEEE Hong Kong Section; and
- Government departments, e.g. the Environmental Protection Department, the Electrical and Mechanical Services Department, Hospital Authority and Department of Health.

A wide variety of resource materials relevant to the Physics Curriculum are readily available from the community, including the following examples:

(1) Projects from tertiary institutions

Tertiary institutions are taking an active role in the development of science learning resource materials for secondary schools. Projects such as *Case-based Learning of High School Science Subjects to Support Learning to Learn* and *Enhancing Senior Secondary Students' Understanding of the Nature of Science and the Interconnection between Science, Technology and Society through Innovative Teaching and Learning Activities* are very useful resources for effective learning of physics.

(2) Learning experience outside schools

Many aspects of the Physics Curriculum are directly related to the local environment. For example, visits to the Hong Kong Science Museum and local universities can enhance students' interest in physics, and develop their understanding of the latest developments in the subject. Also, some physics-related activities, e.g. the Joint Schools Science Exhibition, can provide students with valuable and authentic learning experiences.

Fieldwork allows students to integrate key concepts for knowledge-building, and students who participate in these activities are likely to be more motivated and have a better understanding of phenomena related to physics. Certain organisations, e.g. the Ocean Park Hong Kong and the Ho Koon Nature Education cum Astronomical Centre, offer life-wide learning contexts and, in some cases, guided educational tours for students. Schools can also design learning programmes for their students related to their own communities.

(3) Competitions

Experiences from some local project competitions such as the Hong Kong Student Science Project Competition and the Physics Research Experiences for Sixth Form Students provide valuable ideas for scientific investigations and inventions. Other competitions such as the Hong Kong Physics Olympiad and the International Physics Olympiad present challenges to students with outstanding ability in physics.

(4) Library resources

In both school libraries and public libraries, various printed and multimedia resources can be easily accessed to enhance learning. Promotional activities for reading and learning, such as reading schemes, book exhibitions and talks on reading and learning skills, are useful. Teachers can find supportive resources, such as journals, articles and magazines mentioned in this chapter from the libraries, to facilitate their development of learning and teaching materials. Students can prepare background information for investigative activities, further explore physics-related issues with STSE connections and construct a concrete knowledge basis of the subject in the libraries. The active, frequent and appropriate use of library resources can help students to develop skills for independent learning, cultivate useful reading habits and become independent lifelong learners.

(5) Parents and alumni

Parents and alumni can complement the work in schools. For instance, parents can support the curriculum by providing extended learning experiences outside school, e.g. by discussing the social, moral and ethical issues related to physics with their daughters and sons. They can also use the resources suggested in this Guide and in public libraries to stimulate a sense of inquiry in their daughters and sons; and they can instil in them an appreciation of the value of learning. Parents from different professions can be invited to deliver speeches or lectures to provide opportunities for students to gain authentic knowledge from various disciplines.

Alumni can be a good source of support for student learning. They can be invited to share their experiences of learning the subject at school and of related studies at tertiary level, and discuss possible careers. They can also contribute to schools' special activities such as open days and science funfairs as advisors and speakers. Schools should establish connections with their alumni in the fields related to physics to enrich students' views on the prospects for physics students.

6.4 Use of Learning and Teaching Resources

To assist schools in implementing the senior secondary curriculum, the EDB will continue to provide additional funding and to allow greater flexibility in the use of resources to cater for diverse needs. Schools are advised to refer to the relevant and latest circulars issued by the EDB from time to time.

The successful use of learning and teaching resources can help students to integrate, practise and apply new knowledge. Teachers should utilise both ready-made and self-developed materials flexibly according to the needs, abilities and interests of their students. Textbooks can remain as the basic resource for learning and teaching activities, but should not be the only resource. Teachers need to make judgments when selecting, adapting and modifying relevant resources to suit students' various learning purposes.

Teachers can consider the following points when adapting learning and teaching resources:

- Keep the learning targets and objectives of the curriculum in mind and identify the focus of each topic.
- Select activities that involve interaction and active engagement of students in learning.
- Tailor learning and teaching resources to cater for learner diversity.
- Design challenging activities so that more able learners may omit the easier parts while less able learners may skip the more difficult ones.

For low achievers, the learning and teaching materials should be more organised and systematic in order to build up their understanding of the core elements of the Physics topics first; and then extra resources can be employed to help them to achieve the learning targets, consolidate what they have learned and to construct personal knowledge. For talented students, resources that provide more challenging learning tasks involving higher-order thinking should be employed to strengthen their critical and creative thinking and other generic skills.

6.5 Resource Management

6.5.1 Accessing Useful Resources

Students and teachers should share the responsibility for locating useful learning and teaching resources. For example, teachers can provide students with lists of recommended websites and reference books for particular topics; and students can also search for useful resources from the Internet, libraries, government departments and other community organisations on their own, and make suggestions to enrich the resource lists.

6.5.2 Sharing Resources

Schools should make arrangements and provide the following opportunities to facilitate the sharing of learning and teaching resources:

- Teachers and students share learning and teaching resources through the Intranet, or other means within the school.
- Teachers are encouraged to make good use of well-established web-based platforms, such as the Hong Kong Education City, for sharing information with peers on the latest developments in physics education, learning and teaching experience, as well as locally developed resources for learning and teaching.
- Teachers might reflect on their teaching when using different types of learning and teaching resources, and subsequently exchange experiences with fellow teachers.

6.5.3 Storing Resources

Schools should assign staff to manage the storage of resources and access to them. They should keep up-to-date inventories of learning resources. IT is helpful for managing and storing the materials acquired for Physics. For example, the school Intranet can be used to give students and teachers easy access to suitable resources for specific topics. Software which is commonly available in schools, such as spreadsheet, word processing and database programs can also be useful tools for this purpose. Keeping systematic records and providing easy access to learning and teaching resources and laboratory equipment, can have a significant impact on learning effectiveness.

Physics teachers should work closely with teacher librarians, in both the collection and systematic storage of the resources, and to provide a wide range of reading and learning resources for students. The teacher librarian, as an information specialist, is in the best position to help students to acquire the skills and attitudes necessary for using information appropriately and ethically.

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Appendix 1

Time-tabling Arrangement and the Deployment of Teachers to cater for the Diverse Needs of Students

There are four subjects, namely Biology, Chemistry, Physics and Science (including Mode I and Mode II) offered in the Science Education KLA, leading to a number of possible subject combinations for students. The various subject combinations are considered worthwhile and valuable to serve the needs of students pursuing different post-secondary pathways. Possible ways of managing school time-tabling and resources to allow students more choice are discussed below.

Implementation of Mode I - Integrated Science Curriculum

If this subject is taken by a class of students as a single elective subject, normal time-tabling can be adopted. It is a common practice in schools that a teacher will take up the teaching of a course for three years. However, due to the multi-disciplinary nature of this subject, schools may consider assigning teachers with different expertise to teach this subject at different levels (S4, 5 and 6), or two teachers with different subject expertise to teach one class, so that teachers can focus more on modules that they are familiar with. This also helps to share out the work required to prepare for the curriculum.

We encourage schools to promote partnership in terms of preparation of lessons, team teaching as well as lesson observations so that teachers work and learn together. It is recommended that schools reserve time for collaborative lesson planning in the time-table.

In cases where a school is offering this subject to two or more classes, it is advisable to assign teachers with different subject expertise to different classes. With special time-tabling, it is then possible to swap the classes so that teachers can concentrate on modules that they are more familiar with. After a few years, the teachers will be able to cover the teaching of the whole curriculum and be better placed to monitor the progress of the students.

The following illustrates the different arrangements that schools may adopt according to their resources and the readiness of their teachers:

Option A: One teacher teaches one class for all three levels. The teacher is required to teach beyond his/her own expertise, and so time should be allowed for his/her professional development, knowledge updating and lesson preparation.

Option B: Teachers with different expertise share the teaching of one class. The teachers will be able to concentrate on preparing the modules they are more familiar with.

Option C: Two teachers with different expertise teach two classes, with each teaching one class. There should be regular sharing between the two teachers, helping each other in preparing resources and knowledge enrichment.

Option D: Two teachers with different expertise teach two classes, with a special time-table which allows them to swap their responsibilities at different times during the school year.

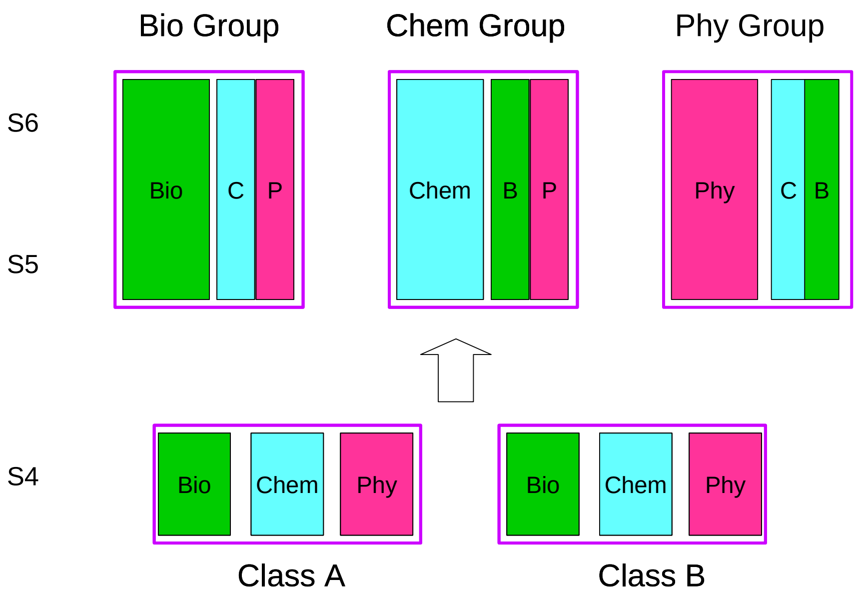
Implementation of Mode II - Combined Science Curriculum

The Combined Science Curriculum is designed for students taking two elective subjects in the Science Education KLA; it comprises three parts with content selected from the Biology, Chemistry and Physics curricula. Students will have to take the two parts that are complementary to the single discipline in which they specialise. Special time-tabling and staff deployment are needed for implementation.

To help students to build up a broader knowledge base, it is recommended that students should be offered more elective subjects in S4 and be guided to select two or three electives to focus on in S5 and S6. Students wishing to take two elective subjects in the Science Education KLA should study parts of Biology, Chemistry and Physics Curricula using the lesson time for two elective subjects in S4. That is, if four periods per cycle are allocated for one elective subject, schools may arrange three periods for each science discipline in S4. Teachers should refer to the respective C&A Guides for a selection of topics suitable to be included in the S4 curriculum to help students to build a broad-based foundation. Schools may consider the following two arrangements in S5 and S6:

(1) Flexible grouping and split class arrangement

Students from two or three different classes are arranged into three groups namely, Biology group, Chemistry group and Physics group depending on the specialised subject they opt for. As illustrated in the diagram below, the students will have four periods per cycle for their specialised subject and two periods per cycle for the other two complementary subjects.



An example of two classes taking two elective subjects from the Science Education KLA

To facilitate the split class arrangement, three common blocks in the time-table have to be arranged for Biology, Chemistry and Physics teachers. That is, in the four periods allocated for the 1st Block, the respective subject teachers will be teaching the groups that have chosen to specialise in their subjects. In the 2nd and 3rd Blocks, they will be spending two lessons each to the groups taking the other two specialised subjects.

	Biology Teacher	**Chemistry Teacher**	**Physics Teacher**
1st Block (4 periods)	Biology (Bio Group)	Chemistry (Chem Group)	Physics (Phy Group)
2nd Block (2 periods)	Biology part of Combined Science (Chem Group)	Chemistry part of Combined Science (Phy Group)	Physics part of Combined Science (Bio Group)
3rd Block (2 periods)	Biology part of Combined Science (Phy Group)	Chemistry part of Combined Science (Bio Group)	Physics part of Combined Science (Chem Group)

(2) Block time-table arrangement

Schools may arrange three common blocks in the time-table for three classes. The three subjects in each block will share the same time slots in the time-table. In each block, students may take any one subject from the three subjects offered in the block.

	Class A	**Class B**	**Class C**
Core subjects	Chin Lang	Chin Lang	Chin Lang
	Eng Lang	Eng Lang	Eng Lang
	Math	Math	Math
	LS	LS	LS
1st Block	Bio / Combined Sci (Chem, Bio) / X from other KLAs		
2nd Block	Chem / Combined Sci (Phy, Chem) / X from other KLAs		
3rd Block	Phy / Combined Sci (Bio, Phy) / X from other KLAs		

Other Classes
Chin Lang
Eng Lang
Math
LS
Integrated Science
X from other KLAs
X from other KLAs

In the above arrangement, X is an elective subject from the other KLAs or an ApL course. Students in Classes A, B and C are offered the following possible choices:

- Biology + 2X
- Chemistry + 2X
- Physics + 2X
- Biology + Combined Science (Phy, Chem) + X
- Chemistry + Combined Science (Bio, Phy) + X
- Physics + Combined Science (Chem, Bio) + X
- Biology + Chemistry + X
- Chemistry + Physics + X
- Biology + Physics + X
- Biology + Chemistry + Physics
- 3X (from other KLAs/ApL course)

From the time-table, it is clear that two teachers of each science discipline are needed. For example, in the third common block, one Physics teacher is needed to teach four lessons of Physics and another Physics teacher is needed to teach the two lessons for the Physics part of the Combined Science (Bio, Phy) Curriculum.

Appendix 2

Periodicals and Journals

1. Physics Education

   http://www.iop.org/journals/physed
   Physics Education is an international journal. Articles are chosen to support secondary school teachers and those involved with courses up to introductory undergraduate level, giving everyone who is teaching physics in schools and colleges the support and information that they need on the latest developments and teaching methods.

2. The Physics Teacher

   http://scitation.aip.org/content/aapt/journal/tpt
   The Physics Teacher publishes papers on physics research, the history and philosophy of physics, applied physics, curriculum developments, pedagogy, instructional laboratory equipment and book reviews.

3. The Science Teacher

   http://www.nsta.org/highschool#journal
   The National Science Teachers Association publishes *The Science Teacher* nine times a year. It is a peer-reviewed scholarly journal for secondary science teachers. There is "special issue's focus" for each periodic.

4. 物理教學探討

   《物理教學探討》is a half-monthly journal for secondary physics teachers. It is one of the major journals published by the South West China Normal University regarding basic education of mainland. It publishes pedagogical papers contributed by academics and secondary physics teachers, with content including forum of specialists, teaching reform, study of teaching materials and methods, and issue discussion.

5. 物理教師

《物理教師》is a monthly journal co-published by the Physics Teaching Professional Commission of the Chinese Society of Education and Soochow University. It publishes papers of physics teaching and physics researches contributed by academics and secondary physics teachers, with content including researches on educational theories, teaching methods and materials, junior secondary corner, physics experiments, famous physicists and physics history, etc.

6. 中學物理

《中學物理》is a half-monthly journal co-published by the Physics Teaching Professional Commission of the Chinese Society of Education and Harbin Normal University. It publishes papers of physics teaching and physics researches contributed by academics and secondary physics teachers, with content including teaching forum, exchange of experience, teaching materials, promotion of physics and micro-teaching, etc.

7. 物理教學

《物理教學》is a monthly journal published by the Chinese Physical Society and managed by the China Association for Science and Technology. It is one of the major and excellent journals by the China Association for Science and Technology on education at middle level. It publishes papers on physics teaching contributed by academics and secondary physics teachers, with content including forum, project research, teaching research, study of pedagogy, physics experiments, pedagogy from overseas and sharing of experiments, etc.

Appendix 3

Resources published by the Education Bureau

1. Physics World

   http://www.hk-phy.org

   At *Physics World*, teachers and students will find a rich and growing collection of teaching resources. This website is subdivided into seven main sections, under the heading of "Introduction", "Teachers", "Physicists", "Resources", "Physics Q&A", "Further Physics" and "Useful Links". The website provides teachers with the resources that are supporting the reforms in the Physics Curriculum. Most resource materials (e.g. worksheets, PowerPoint presentations, video clips and diagrams) are accessible by the general public while some teaching materials are for registered users only. *Physics World* is a dynamic site with new content being added on a regular basis.

2. Contextual Physics

   http://www.hk-phy.org/contextual/

   The homepage of this website offers an extensive collection of links to resources in teaching, tryouts, curriculum and references to advocate contextual approach in physics teaching. Forum and sharing area for teachers are also provided. Topics include "Motion", "Force", "Momentum", "Energy", "Temperature", "Heat", "Heat Transfer" and "Change of States" to support the contextual approach.

3. Ocean Park Physics

   http://www.hk-phy.org/oceanpark/

   This website provides resource materials to support learning beyond classroom. Learning activities, worksheet and video clips for "Turbo Drop", "Cable Car", "Ocean Theatre", "Roller Coaster" and "Tower in the Ocean Park" are provided for download. Teachers can also download "Motion Video Analysis" software to analyse the motion of an object (e.g. dolphin high jump and turbo drop) in the video clips.

4. Using Datalogger in the Teaching of Physics

   http://data-log.hkedcity.net/physics/index.html

   This website provides a comprehensive collection of teaching resource materials for using data logger in the teaching of physics. Topics include "Mechanics", "Electricity and Magnetism", "Optics and Waves", and "Heat and Energy". Within each topic there is collection of experiments and suggested teaching activities. From the homepage access is available to such areas as the operation, interface, sensor, software and vendor.

5. Reading to Learn

http://resources.edb.gov.hk/physics/index_e.html

The Enhancing Science Learning through Electronic Library provides physics teachers with resources for promoting reading to learn. Essays from local physicists are provided both in English and Chinese versions. These essays cover a wide range of subject areas that will lead students to interesting reading on bridges, buildings, integrated circuits, lasers, microwaves, laser speed detection, telecommunication, solar power, smart materials, binary stars, and others. This website is full of links that will lead teachers and students to extensive reading materials. Follow-up activities and suggested teaching activities are provided so that many readers can make use of it.

6. Glossary in Physics

http://cd1.edb.hkedcity.net/cd/science/glossarysci_eng.html

This website provides an interactive web-based platform for teachers and students to find English-Chinese glossary of terms commonly used in the teaching of physics in secondary schools. Key words search is offered.

7. Subject web-site in HKEdCity – Physics

http://iworld.hkedcity.net/physics

This website offers a platform to share teaching ideas, mock examination tests, lesson plans, laboratory activities, video clips and photos among physics teachers. Under "Share Resources Section", there are interesting and useful resources for download. The website also posts news, forum, useful links and teacher training programs for teachers.

8. Energy Efficiency

http://www.hk-phy.org/energy/index_e.html

This site provides a very comprehensive information related to (1) power production, (2) domestic energy efficiency, (3) commercial/industrial energy efficiency and (4) alternative sources of energy to support the "Energy and Use of Energy" of the Elective Part in the Physics Curriculum. Worksheets, video clips and Flash animation programmes are provided for registered users. It also includes an interactive e-learning platform to foster cyber-learning for Energy and Use of Energy.

9. Atomic World

http://www.hk-phy.org/atomic_world

The web site consists of comprehensive and organized materials on the part of nano science in the elective topic Atomic World of the NSS Physics Curriculum. Ready-made materials, e.g. learning activities and animations of different carbon molecule structures, working principles of transmission electronic microscope and scanning tunneling microscope atoms, can be downloaded for teaching and self-directed learning.

10. Medical Physics

http://www.hkedcity.net/article/project/medicalphysics/

This website provides interactive learning and teaching exemplars for teachers to delivery abstract concepts in medical imaging. Exemplars are presented in a graphic format with interactive animations. Topics such as medical imaging using non-ionization radiation (e.g. A-scan and B-scan) and ionization radiation (radiographic images and CT) are included. Learning objectives, background information, activities and questions with answers are offered by the website for teacher reference.

11. Writing and Application of Physics Specific Genres

http://edb.hkedcity.net/phygenres/en/index.htm

This website contains notes on genres, instructional design, on-line interactive exercises and relevant reference materials of the commonly-used physics specific genres. Teachers can make use of these materials to teach students the physics specific genres and ultimately help them improve their writing skills in physics.

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Glossary

Term	Description
Applied Learning (ApL, formerly known as Career-oriented Studies)	Applied Learning (ApL, formerly known as Career-oriented Studies) is an essential component of the senior secondary curriculum. ApL uses broad professional and vocational fields as the learning platform, developing students' foundation skills, thinking skills, people skills, values & attitudes and career-related competencies, to prepare them for further studies and/or for work as well as for lifelong learning. ApL courses complement 24 subjects, diversifying the senior secondary curriculum.
Assessment objectives	The outcomes of the curriculum to be assessed in the public assessments.
Biliterate and trilingual	Capable of reading and writing effectively in Standard Written Chinese, English and to use Cantonese, Putonghua and spoken English. The language education policy of Hong Kong is to enable the Hong Kong students to become biliterate (in written Chinese and English) and trilingual (in Cantonese, Putonghua and spoken English).
Co-construction	Different from the direct instruction and construction approaches to learning and teaching, the co-construction approach emphasises the class as a community of learners who contribute collectively to the creation of knowledge and the building of criteria for judging such knowledge.
Core subjects	Subjects recommended for all students to take at senior secondary level: Chinese Language, English Language, Mathematics and Liberal Studies.
Curriculum and Assessment (C&A) Guide	A guide prepared by the CDC-HKEAA Committee. It embraces curriculum aims/objectives/contents and learning outcomes, and assessment guidelines.

Term	Description
Curriculum interface	Curriculum interface refers to the interface between the different key stages/educational stages of the school curriculum (including individual subjects), e.g. the interface between Kindergarten and Primary; Primary and Secondary; and Junior Secondary and Senior Secondary. The Hong Kong school curriculum, made up of eight key learning areas (under which specific subjects are categorised), provides a coherent learning framework to enhance students' capabilities for whole-person development through engaging them in the five essential learning experiences and helping them develop the nine generic skills as well as positive values and attitudes. Thus when students move on to senior secondary education, they will already have developed the basic knowledge and skills that the study of various subjects requires. When designing the learning and teaching content and strategies, teachers should build on the knowledge and learning experiences students have gained in the previous key stages.
Elective subjects	A total of 20 subjects in the proposed system from which students may choose according to their interests, abilities and aptitudes.
Generic skills	Generic skills are skills, abilities and attributes which are fundamental in helping students to acquire, construct and apply knowledge. They are developed through the learning and teaching that take place in different subjects or key learning areas, and are transferable to different learning situations. Nine types of generic skills are identified in the Hong Kong school curriculum, i.e. collaboration skills, communication skills, creativity, critical thinking skills, information technology skills, numeracy skills, problem-solving skills, self-management skills and study skills.
Hong Kong Diploma of Secondary Education (HKDSE)	The qualification to be awarded to students after completing the three-year senior secondary curriculum and taking the public assessment.
Internal assessment	This refers to the assessment activities that are conducted regularly in school to assess students' performance in learning. Internal assessment is an inseparable part of the learning and teaching process, and it aims to make learning more effective. With the information that internal assessment provides, teachers will be able to understand students' progress in learning, provide them with appropriate feedback and make any adjustments to the learning objectives and teaching strategies they deem necessary.

Term	Description
Key Learning Area (KLA)	Organisation of the school curriculum structured around fundamental concepts of major knowledge domains. It aims at providing a broad, balanced and coherent curriculum for all students in the essential learning experiences. The Hong Kong curriculum has eight KLAs, namely, Chinese Language Education, English Language Education, Mathematics Education, Personal, Social and Humanities Education, Science Education, Technology Education, Arts Education and Physical Education.
Knowledge construction	This refers to the process of learning in which learners are involved not only in acquiring new knowledge, but also in actively relating it to their prior knowledge and experience so as to create and form their own knowledge.
Learning community	A learning community refers to a group of people who have shared values and goals, and who work closely together to generate knowledge and create new ways of learning through active participation, collaboration and reflection. Such a learning community may involve not only students and teachers, but also parents and other parties in the community.
Learning differences	This refers to the gaps in learning that exist in the learning process. Catering for learning differences does not mean rigidly reducing the distance between the learners in terms of progress and development but making full use of their different talents as invaluable resources to facilitate learning and teaching. To cater to learners' varied needs and abilities, it is important that flexibility be built into the learning and teaching process to help them recognise their unique talents and to provide ample opportunities to encourage them to fulfil their potential and strive for achievement.
Learning outcomes	Learning outcomes refer to what learners should be able to do by the end of a particular stage of learning. Learning outcomes are developed based on the learning targets and objectives of the curriculum for the purpose of evaluating learning effectiveness. Learning outcomes also describe the levels of performance that learners should attain after completing a particular key stage of learning and serve as a tool for promoting learning and teaching.

Term	Description
Learning targets and learning objectives	• Learning targets set out broadly the knowledge/concepts, skills, values and attitudes that students need to learn and develop. • Learning objectives define specifically what students should know, value and be able to do in each strand of the subject in accordance with the broad subject targets at each key stage of schooling. They are to be used by teachers as a source list for curriculum, lesson and activity planning.
Level descriptors	A set of written descriptions that describe what the typical candidates performing a certain level is able to do in public assessments.
Other learning experiences	For whole person development of students, 'Other Learning Experiences' (OLE) is one of the three components that complement the examination subjects and Applied Learning (formerly named as Career-oriented Studies) under the senior secondary curriculum. It includes Moral and Civic Education, Aesthetics Development, Physical Development, Community Service and Career-related Experiences.
Public assessment	The associated assessment and examination system for the Hong Kong Diploma of Secondary Education.
SBA Moderation Mechanism	The mechanism adopted by HKEAA to adjust SBA marks submitted by schools to iron out possible differences across schools in marking standards and without affecting the rank order determined by the school.
School-based assessment (SBA)	Assessments administered in schools as part of the teaching and learning process, with students being assessed by their subject teachers. Marks awarded will count towards students' public assessment results.
School-based curriculum	Schools and teachers are encouraged to adapt the central curriculum to develop their school-based curriculum to help their students achieve the subject targets and overall aims of education. Measures may include readjusting the learning targets, varying the organisation of contents, adding optional studies and adapting learning, teaching and assessment strategies. A school-based curriculum, hence, is the outcome of a balance between official recommendations and the autonomy of the schools and teachers.
Standards-referenced Reporting	Candidates' performance in public assessment is reported in terms of levels of performance matched against a set of standards.

Term	**Description**
Student diversity	Students are individuals with varied family, social, economic and cultural backgrounds and learning experience. They have different talents, personalities, intelligence and interests. Their learning abilities, interests and styles are, therefore, diverse.
Student learning profile	It is to provide supplementary information on the secondary school leavers' participation and specialties during senior secondary years, in addition to their academic performance as reported in the Hong Kong Diploma of Secondary Education, including the assessment results for Applied Learning courses, thus giving a fuller picture of the student's whole person development.
Values & attitudes	Values constitute the foundation of the attitudes and beliefs that influence one's behaviour and way of life. They help form principles underlying human conduct and critical judgment, and are qualities that learners should develop. Some examples of values are rights and responsibilities, commitment, honesty and national identity. Closely associated with values are attitudes. The latter supports motivation and cognitive functioning, and affects one's way of reacting to events or situations. Since both values and attitudes significantly affect the way a student learns, they form an important part of the school curriculum.

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(From December 2003 to September 2013)

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	Dr PANG Wing-chung	(until September 2005)
Members:	Prof HUI Pak-ming	(until September 2005)
	Mr LAU Kwok-leung	
	Mr LEE Wai-kit	
	Prof MAK Se-yuen	
	Dr NG Pun-hon	
	Prof NG Tai-kai	(until November 2006)
	Mr WAN Ka-kit	
	Dr WONG Siu-ling, Alice	(until September 2005)
	Mr WONG Wai-keung	
	Ms YAU Wing-yee	(from November 2005)
	Dr KWOK Ping-wai	(from November 2005)
Ex-officio Members:	Mr LO Chi-lap (EDB)	(until December 2009)
	Mr YU Hon-yui (EDB)	(from December 2009 to June 2010)
	Ms LUI Mong-yu, Grace (EDB)	(from June 2010 to April 2012)
	Dr LAU Yiu-hon (EDB)	(from April 2012)
	Mr SZETO Yuk-tong (HKEAA)	
Secretary:	Mr YU Hon-yui (EDB)	(until December 2009)
	Dr LAU Yiu-hon (EDB)	(from December 2009 to April 2012)
	Mr LIU Sing-po (EDB)	(from April 2012)

Membership of the CDC-HKEAA Committee on Physics

(From September 2013 to August 2015)

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	Dr KWOK Ping-wai		
	Mr LAW Man-wai		
	Mr LEUNG Ngai-chung		
	Dr LO Wai-chau, Edward		
	Dr NG Pun-hon		
	Mr WONG Kim-wah		
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	Mr YING Pui-chi, Bosco		
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	Mr CHOI Chit-kai	(EDB)	(from January 2014)
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Membership of the CDC-HKEAA Committee on Physics

(From September 2015 to August 2017)

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	Mr LEUNG Ngai-chung
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	Dr LO Wai-chau, Edward
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