## 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<br>• interpret temperature as a quantity associated with the average kinetic energy due to the random motion of molecules in a system<br>• explain the use of temperature-dependent properties in measuring temperature<br>• 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<br>• describe the effect of mass, temperature and state of matter on the internal energy of a system<br>• 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 $c = \frac{Q}{m\Delta T}$<br>• determine the specific heat capacity of a substance<br>• discuss the practical importance of the high specific heat capacity of water<br>• 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<br>• interpret energy transfer by conduction in terms of molecular motion<br>• realise the emission of infra-red radiation by hot objects<br>• 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<br>• determine the melting point and boiling point |
| latent heat | • realise latent heat as the energy transferred during the change of state without temperature change<br>• interpret latent heat in terms of the change of potential energy of the molecules during a change of state<br>• define specific latent heat of fusion as $\ell_f = \frac{Q}{m}$<br>• define specific latent heat of vaporization as $\ell_v = \frac{Q}{m}$<br>• solve problems involving latent heat |
| evaporation | • realise the occurrence of evaporation below boiling point<br>• explain the cooling effect of evaporation<br>• discuss the factors affecting rate of evaporation<br>• explain evaporation in terms of molecular motion |
| **d. Gases** | |
| general gas law | • realise the existence of gas pressure<br>• verify Boyle's law<br>• determine pressure-temperature and volume-temperature relationships of a gas<br>• determine absolute zero by the extrapolation of pressure-temperature or volume-temperature relationships<br>• use kelvin as a unit of temperature<br>• combine the three relationships ($p$-$V$, $p$-$T$ and $V$-$T$) of a gas to obtain the relationship $\frac{pV}{T}$ = constant<br>• apply the general gas law $pV = nRT$ to solve problems |
| kinetic theory | • realise the random motion of molecules in a gas<br>• realise the gas pressure resulted from molecular bombardment<br>• 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<br>• realize $pV = \frac{Nm\overline{c^2}}{3}$ that connects micropic and macroscopic quantities of an ideal gas and solve problems<br>• interpret temperature of an ideal gas using $K.E._{\text{average}} = \frac{3RT}{2N_A}$<br>• realise the condition that at high temperature and low pressure a real gas behaves as an ideal gas<br>• 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<br>• present information on displacement-time graphs for moving objects |
| scalars and vectors | • distinguish between scalar and vector quantities<br>• 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<br>• distinguish between instantaneous and average speed/velocity<br>• describe the motion of objects in terms of speed and velocity<br>• present information on velocity-time graphs for moving objects<br>• 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<br>• solve problems involving displacement, time and velocity |
| acceleration | • define acceleration as the rate of change of velocity<br>• use velocity-time graphs to determine the acceleration of objects in uniformly accelerated motion<br>• present information on acceleration-time graphs for moving objects |
| equations of uniformly accelerated motion | • derive equations of uniformly accelerated motion<br>$v = u + at$<br>$s = \frac{1}{2}(u + v)t$<br>$s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$<br>• 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<br>• present graphically information on vertical motions under gravity<br>• apply equations of uniformly accelerated motion to solve problems involving objects in vertical motion<br>• 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<br>• state Newton's First Law of motion and use it to explain situations in which objects are at rest or in uniform motion<br>• 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<br>• 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<br>• state Newton's Second Law of motion and verify $F = ma$ experimentally<br>• use newton as a unit of force<br>• use free-body diagrams to show the forces acting on objects<br>• determine the net force acting on object(s)<br>• 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<br>• 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<br>• 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<br>• discuss the uses of torques and couples<br>• state the conditions for equilibrium of forces acting on a rigid body and solve problems involving a fixed pivot<br>• 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><br>• <u>understand the independence of horizontal and vertical motions</u><br>• <u>solve problems involving projectile motion</u> |
| **d. Work, energy and power** | |
| mechanical work | • interpret mechanical work as a way of energy transfer<br>• define mechanical work done $W = Fs\cos\theta$<br>• 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<br>• derive $P.E. = mgh$<br>• 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<br>• derive $K.E. = \frac{1}{2}mv^2$<br>• solve problems involving kinetic energy |
| law of conservation of energy in a closed system | • state the law of conservation of energy<br>• discuss the inter-conversion of P.E. and K.E. with consideration of energy loss<br>• solve problems involving conservation of energy |

| **Students should learn:** | **Students should be able to:** |
|---|---|
| power | • define power as the rate of energy transfer<br>• 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<br>• 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<br>• distinguish between elastic and inelastic collisions<br>• 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><br>• <u>state centripetal acceleration $a = \frac{v^2}{r}$ and apply it to solve problem involving uniform circular motion</u><br>• <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><br>• <u>define gravitational field strength as force per unit mass</u><br>• <u>determine the gravitational field strength at a point above a planet</u><br>• <u>determine the velocity of an object in a circular orbit</u><br>• <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<br>• 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<br>• describe wave motion in terms of waveform, crest, trough, compression, rarefaction, wavefront, phase, displacement, amplitude, period, frequency, wavelength and wave speed<br>• present information on displacement-time and displacement-distance graphs for travelling waves<br>• determine factors affecting the speed of propagation of waves along stretched strings or springs<br>• 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<br>• realise the refraction of waves across a plane boundary<br>• examine the change in wave speeds during refraction and define refractive index in terms of wave speeds<br>• draw wavefront diagrams to show reflection and refraction |
| diffraction and interference | • describe the diffraction of waves through a narrow gap and around a corner<br>• examine the effect of the width of slit on the degree of diffraction<br>• describe the superposition of two pulses<br>• realise the interference of waves<br>• distinguish between constructive and destructive interferences<br>• examine the interference of waves from two coherent sources<br>• determine the conditions for constructive and destructive interferences in terms of path difference<br>• draw wavefront diagrams to show diffraction and interference |
| stationary wave (transverse waves only) | • explain the formation of a stationary wave<br>• 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 $3.0 \times 10^8$ m s$^{-1}$<br>• state the range of wavelengths for visible light<br>• state the relative positions of visible light and other parts of the electromagnetic spectrum |
| reflection of light | • state the laws of reflection<br>• construct images formed by a plane mirror graphically |
| refraction of light | • examine the laws of refraction<br>• sketch the path of a ray refracted at a boundary<br>• realise $n = \frac{\sin i}{\sin r}$ as the refractive index of a medium<br>• solve problems involving refraction at a boundary |
| total internal reflection | • examine the conditions for total internal reflection<br>• solve problems involving total internal reflection at a boundary |
| formation of images by lenses | • construct images formed by converging and diverging lenses graphically<br>• distinguish between real and virtual images<br>• <u>apply $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ to solve problems for a single thin lens</u><br><u>(using the convention "REAL is positive")</u> |
| wave nature of light | • point out light as an example of transverse wave<br>• realise diffraction and interference as evidences for the wave nature of light<br>• examine the interference patterns in the Young's double slit experiment<br>• <u>apply $\Delta y = \frac{\lambda D}{a}$ to solve problems</u> |

| Students should learn: | Students should be able to: |
|---|---|
| | • examine the interference patterns in the plane transmission grating<br>• <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<br>• realise that sound can exhibit reflection, refraction, diffraction and interference<br>• realise the need for a medium for sound transmission<br>• compare the general properties of sound waves and those of light waves |
| audible frequency range | • determine the audible frequency range<br>• examine the existence of ultrasound beyond the audible frequency range |
| musical notes | • compare musical notes using pitch, loudness and quality<br>• relate frequency and amplitude with the pitch and loudness of a note respectively |
| noise | • represent sound intensity level using the unit decibel<br>• 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<br>• realise the attraction and repulsion between charges<br>• state Coulomb's law $F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$<br>• interpret charging in terms of electron transfer<br>• 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<br>• represent an electric field using field lines<br>• explain how charges interact via an electric field<br>• define electric field strength $E$ at a point as the force per unit charge on a positive test charge placed at that point<br>• <u>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</u> |
| **b. Circuits and domestic electricity** | |
| electric current | • define electric current as the rate of flow of electric charges<br>• state the convention for the direction of electric current |
| electrical energy and electromotive force | • describe the energy transformations in electric circuits<br>• 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<br>• 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 $R=\frac{V}{I}$<br>• describe the variation of current with applied p.d. in metal wires, electrolytes, filament lamps and diodes<br>• realise Ohm's law as a special case of resistance behaviour<br>• 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<br>• derive the resistance combinations in series and parallel<br>$R = R_1 + R_2 + \ldots\ldots$ for resistors connected in series<br>$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$ for resistors connected in parallel |
| simple circuits | • measure $I$, $V$ and $R$ in simple circuits<br>• assign the electrical potential of any earthed points as zero<br>• 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<br>• explain the effects of resistance of ammeters and voltmeters on measurements<br>• solve problems involving simple circuits |
| electrical power | • examine the heating effect when a current passes through a conductor<br>• apply $P = VI$ to solve problems |
| domestic electricity | • determine the power rating of electrical appliances<br>• use kilowatt-hour (kW h) as a unit of electrical energy<br>• calculate the costs of running various electrical appliances<br>• understand household wiring and discuss safety aspects of domestic electricity<br>• determine the operating current for electrical appliances<br>• 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<br>• examine the magnetic field in the region around a magnet<br>• describe the behaviour of a compass in a magnetic field<br>• 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<br>• examine the magnetic field patterns associated with currents through a long straight wire, a circular coil and a long solenoid<br>• apply $B = \frac{\mu_o I}{2\pi r}$ and $B = \frac{\mu_o N I}{l}$ to represent the magnetic fields around a long straight wire, and inside a long solenoid carrying current, and solve related problems<br>• 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<br>• determine the factors affecting the force on a straight current-carrying wire in a magnetic field and represent the force by $F = BIl \sin\theta$<br>• determine the turning effect on a current-carrying coil in a magnetic field<br>• describe the structure of a simple d.c. motor and how it works<br>• solve problems involving current-carrying conductors in a magnetic field<br>• <u>represent the force on a moving charge in a magnetic field by $F = BQv \sin\theta$ and solve problems</u> |
| 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<br>• define magnetic flux $\Phi = BA\cos\theta$ and weber (Wb) as a unit of magnetic flux<br>• interpret magnetic field $B$ as magnetic flux density<br>• state Faraday's Law as $\varepsilon = -\frac{\Delta\Phi}{\Delta t}$ and apply it to calculate the average induced e.m.f.<br>• examine magnetic fields using a search coil<br>• describe the structures of simple d.c. and a.c. generators and how they work<br>• discuss the occurrence and practical uses of eddy currents |
| alternating currents (a.c.) | • distinguish between direct currents (d.c.) and alternating currents (a.c.)<br>• 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.<br>• relate the r.m.s. and peak values of an a.c. |
| transformer | • describe the structure of a simple transformer and how it works<br>• relate the voltage ratio to turn ratio by $\frac{V_P}{V_S} = \frac{N_P}{N_S}$ and apply it to solve problems<br>• examine methods for improving the efficiency of a transformer |
| high voltage transmission of electrical energy | • discuss the advantages of transmission of electrical energy with a.c. at high voltages<br>• describe various stages of stepping up and down of the voltage in a grid system for power transmission |

***(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<br>• realise the emission of X-rays when fast electrons hit a heavy metal target<br>• discuss the uses of X-rays |
| $\alpha$, $\beta$ and $\gamma$ radiations | • describe the origin and nature of $\alpha$, $\beta$ and $\gamma$ radiations<br>• compare $\alpha$, $\beta$ and $\gamma$ 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<br>• 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<br>• define half-life as the period of time over which the number of radioactive nuclei decreases by a factor of one-half<br>• determine the half-life of a radioisotope from its decay graph or from numerical data<br>• realise the existence of background radiation<br>• solve problems involving radioactive decay<br>• <u>represent the number of undecayed nuclei by the exponential law of decay $N = N_o e^{-kt}$</u><br>• <u>apply the exponential law of decay $N = N_o e^{-kt}$ to solve problems</u><br>• <u>relate the decay constant and the half-life</u> |
| detection of radiation | • detect radiation with a photographic film and GM counter<br>• detect radiation in terms of count rate using a GM counter |
| radiation safety | • represent radiation equivalent dose using the unit sievert (Sv)<br>• discuss potential hazards of ionizing radiation and the ways to minimise the radiation dose absorbed<br>• suggest safety precautions in handling radioactive sources |
| **b. Atomic model** | |
| atomic structure | • describe the structure of an atom<br>• 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<br>• use symbolic notations to represent nuclides |
| isotopes and radioactive transmutation | • define isotope<br>• realise the existence of radioactive isotopes in some elements<br>• discuss uses of radioactive isotopes<br>• represent radioactive transmutations in $\alpha$, $\beta$ and $\gamma$ 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<br>• realise nuclear chain reaction<br>• realise nuclear fusion as the source of solar energy |
| mass-energy relationship | • state mass-energy relationship $\Delta E = \Delta m\, c^2$<br>• use atomic mass unit as a unit of energy<br>• determine the energy release in nuclear reactions<br>• apply $\Delta E = \Delta m\, c^2$ to solve problems |

***(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<br>• 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<br>• describe Galileo's astronomical discoveries and discuss their implications<br>• 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<br>• derive Kepler's third law $T^2 \propto r^3$ for circular orbits from Newton's law of gravitation<br>• state Kepler's third law for elliptical orbits $T^2 = \frac{4\pi^2 a^3}{GM}$<br>• 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 $U = -\frac{GMm}{r}$<br>• apply conservation of mechanical energy to solve problems involving the motion of celestial bodies or spacecraft<br>• 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<br>• use parsec (pc) as a unit of distance<br>• realise magnitude as a measure of brightness of celestial bodies<br>• distinguish between apparent magnitude and absolute magnitude<br>• describe the effect of surface temperature on the colour and luminosity of a star using blackbody radiation curves<br>• realise the existence of spectral lines in the spectra of stars<br>• 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<br>• represent information of classification for stars on the Hertzsprung-Russell (H-R) diagram according to their luminosities and surface temperatures<br>• 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<br>• 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<br>• relate the rotation curve of stars around galaxies to the existence of dark matter<br>• 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<br>• state the limitations of Rutherford's atomic model in accounting for the motion of electrons around the nucleus and line spectra<br>• 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<br>• 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 $E = hf$<br>• describe how the intensity of the incident light of a given frequency is related to the number of photons<br>• explain photoelectric effect using Einstein's photoelectric equation $hf - \phi = \frac{1}{2} m_e v_{max}{}^2$<br>• realise the photoelectric effect as the evidence of particle nature of light<br>• 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<br>• explain spectral lines in terms of difference in energies<br>• realise that the energy of a hydrogen atom can only take on certain values<br>• 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<br>• distinguish between the "quantum" and "classical" aspects in the postulates of Bohr's atomic model of hydrogen<br>• 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<br>• 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<br>• use electron-volt (eV) as a unit of energy<br>• distinguish ionization and excitation energies<br>• 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<br>• interpret line spectra by the use of Bohr's equation of electron energy<br>• 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<br>• describe evidences of electrons and light exhibiting both wave and particle properties<br>• relate the wave and particle properties of electrons using the de Broglie formula $\lambda=\frac{h}{p}$<br>• apply $\lambda=\frac{h}{p}$ to solve problems |
| **e. Probing into nano scale** | |
| physical properties of materials in nano scale | • understand that nano means $10^{-9}$<br>• realise that materials in nano scale can exist in various forms, such as nano wires, nano tubes and nano particles<br>• 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<br>• describe how a transmission electron microscope (TEM) works<br>• draw the analogy between the use of electric and magnetic fields in TEMs and lenses in optical microscopes<br>• estimate the anode voltage needed in a TEM to accelerate electrons achieving wavelengths of the order of atomic size<br>• 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<br>• 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 $\alpha$ 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<br>• describe the energy conversion involved in electrical appliances<br>• 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<br>• 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<br>• discuss cost effectiveness of incandescent lamps, gas discharge lamps and light emitting diodes<br>• realise that the eye response depends on wavelengths<br>• define luminous flux as the energy of light emitted per unit time by a light source<br>• use lumen as a unit of luminous flux<br>• define illuminance as luminous flux falling on unit area of a surface<br>• use lux as a unit of illuminance<br>• use inverse square law and Lambert's cosine law to solve problems involving illuminance<br>• 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<br>• solve problems involving end-use energy efficiency of cookers<br>• 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<br>• 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<br>• define coefficient of performance COP as ratio of cooling capacity to electrical power input and solve related problems<br>• 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<br>• solve problems involving EELS<br>• 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<br>• define thermal transmittance U-value of building materials as $u = \frac{\kappa}{d}$ and solve related problems<br>• 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<br>• discuss factors affecting the OTTV<br>• discuss the use of solar control window film in a building<br>• 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<br>• discuss the use of electric vehicles<br>• state the main components of the power system of hybrid vehicles and compare their end-use energy efficiency to fossil-fuel vehicles<br>• 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<br>• 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<br>• solve problems involving the solar constant[3]<br>• derive maximum power by wind turbine as $P = \frac{1}{2}\eta\rho A v^3$, where $\eta$ is the efficiency and solve problems<br>• describe the energy conversion process for hydroelectric power and solve problems<br>• define binding energy per nucleon in unit of eV and solve problems<br>• relate the binding energy curve to nuclear fission and fusion<br>• describe the principle of the fission reactor and state the roles of moderator, coolant and control rods<br>• 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<br>• discuss effect of greenhouse gases on global warming<br>• 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