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For the Working Group on Physics Syllabus Change in Schools, School of Physics

The University of Sydney

Module 1: Kinematics

Outcomes

A student:

› designs and evaluates investigations in order to obtain primary and secondary data and information PH11/12- 2

› conducts investigations to collect valid and reliable primary and secondary data and information PH11/12-3

› selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4

› analyses and evaluates primary and secondary data and information PH11/12-5

› solves scientific problems using primary and secondary data, critical thinking skills and scientific processes PH11/12-6

› describes and analyses motion in terms of scalar and vector quantities in two dimensions and makes quantitative measurements and calculations for distance, displacement, speed, velocity and acceleration PH11-8

Content Focus

Motion is a fundamental observable phenomenon. The study of kinematics involves describing, measuring and analysing motion without considering the forces and masses involved in that motion. Uniformly accelerated motion is described in terms of relationships between measurable scalar and vector quantities, including displacement, speed, velocity, acceleration and time.

Representations – including graphs and vectors, and equations of motion – can be used qualitatively and quantitatively to describe and predict linear motion.

By studying this module, students come to understand that scientific knowledge enables scientists to offer valid explanations and make reliable predictions, particularly in regard to the motion of an object.

Working Scientifically

In this module, students focus on designing, evaluating and conducting investigations to examine trends in data and solve problems related to kinematics. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Motion in a Straight Line

Inquiry question: How is the motion of an object moving in a straight line described and predicted?

Students:

- describe uniform straight-line (rectilinear) motion and uniformly accelerated motion through:
  - qualitative descriptions
  - the use of scalar and vector quantities (ACSPH060)
- conduct a practical investigation to gather data to facilitate the analysis of instantaneous and average velocity through:
  - quantitative, first-hand measurements
  - the graphical representation and interpretation of data (ACSPH061) 8.4.1

emphasis on vectors

- calculate the relative velocity of two objects moving along the same line using vector analysis
- conduct practical investigations, selecting from a range of technologies, to record and analyse the motion of objects in a variety of situations in one dimension in order to measure or calculate:
  - time
  - distance
  - displacement
  - speed
  - velocity
  - acceleration

  additions to 8.4.1 / 8.4.2
- use mathematical modelling and graphs, selected from a range of technologies, to analyse and derive relationships between time, distance, displacement, speed, velocity and acceleration in rectilinear motion, including:
  - $\vec{s} = \vec{u}t + \frac{1}{2}\vec{a}t^2$
  - $\vec{v} = \vec{u} + \vec{a}t$
  - $\vec{v}^2 = \vec{u}^2 + 2\vec{a}\vec{s}$ (ACSPH061)

  moved in from Year 12 to Year 11 9.2.2

Motion on a Plane

Inquiry question: How is the motion of an object that changes its direction of movement on a plane described?

Students:

- analyse vectors in one and two dimensions to:
  - resolve a vector into two perpendicular components
  - add two perpendicular vector components to obtain a single vector (ACSPH061) – 8.4.2
- represent the distance and displacement of objects moving on a horizontal plane using:
  - vector addition
  - resolution of components of vectors (ACSPH060) – 8.4.2
- describe and analyse algebraically, graphically and with vector diagrams, the ways in which the motion of objects changes, including:
  - velocity
  - displacement (ACSPH060, ACSPH061)
- describe and analyse, using vector analysis, the relative positions and motions of one object relative to another object on a plane (ACSPH061)
- analyse the relative motion of objects in two dimensions in a variety of situations, for example:
  - a boat on a flowing river relative to the bank
  - two moving cars
  - an aeroplane in a crosswind relative to the ground (ACSPH060, ACSPH132)

[green] = new to syllabus

[yellow] = modified from current syllabus

[pink] = moved from 'Options' to new syllabus

Module 2: Dynamics

Outcomes

A student:

- designs and evaluates investigations in order to obtain primary and secondary data and information PH11/12-2
- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4
- solves scientific problems using primary and secondary data, critical thinking skills and scientific processes PH11/12-6
- describes and explains events in terms of Newton's Laws of Motion, the law of conservation of momentum and the law of conservation of energy PH11-9

Content Focus

The relationship between the motion of objects and the forces that act on them is often complex. However, Newton's Laws of Motion can be used to describe the effect of forces on the motion of single objects and simple systems. This module develops the key concept that forces are always produced in pairs that act on different objects and add to zero.

By applying Newton's laws directly to simple systems, and, where appropriate, the law of conservation of momentum and law of conservation of mechanical energy, students examine the effects of forces. They also examine the interactions and relationships that can occur between objects by modelling and representing these using vectors and equations.

In many situations, within and beyond the discipline of physics, knowing the rates of change of quantities provides deeper insight into various phenomena. In this module, the rates of change of displacement, velocity and energy are of particular significance and students develop an understanding of the usefulness and limitations of modelling.

Working Scientifically

In this module, students focus on designing, evaluating and conducting investigations and interpreting trends in data to solve problems related to dynamics. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Forces

Inquiry question: How are forces produced between objects and what effects do forces produce?

Students:

- using Newton's Laws of Motion, describe static and dynamic interactions between two or more objects and the changes that result from:
  - a contact force
  - a force mediated by fields ← 8.4.2
- explore the concept of net force and equilibrium in one-dimensional and simple two-dimensional contexts using: (ACSPH050)
  - algebraic addition

↑ new to 8.4.2

↙ vector emphasis

  - vector addition
  - vector addition by resolution into components
- solve problems or make quantitative predictions about resultant and component forces by applying the following relationships:
  - $\vec{F}_{AB} = -\vec{F}_{BA}$
  - $\vec{F}_x = \vec{F}cos\theta, \vec{F}_y = \vec{F}sin\theta$
- conduct a practical investigation to explain and predict the motion of objects on inclined planes (ACSPH098)

Forces, Acceleration and Energy

Inquiry question: How can the motion of objects be explained and analysed?

↙ addition of 1st law to 8.4.2

Students:

- apply Newton's first two laws of motion to a variety of everyday situations, including both static and dynamic examples, and include the role played by friction ($friction = \mu \vec{F}_N$) (ACSPH063)
- investigate, describe and analyse the acceleration of a single object subjected to a constant net force and relate the motion of the object to Newton's Second Law of Motion through the use of: (ACSPH062, ACSPH063)
  - qualitative descriptions
  - graphs and vectors
  - deriving relationships from graphical representations including $\vec{F} = m\vec{a}$ and relationships of uniformly accelerated motion] 8.4.2
- apply the special case of conservation of mechanical energy to the quantitative analysis of motion involving:
  - work done and change in the kinetic energy of an object undergoing accelerated rectilinear motion in one dimension ($W = \vec{F}_{net}\vec{s}$)
  - changes in gravitational potential energy of an object in a uniform field ($\Delta U = m\vec{g}\Delta\vec{h}$) – 8.4.3
- conduct investigations over a range of mechanical processes to analyse qualitatively and quantitatively the concept of average power ($P = \frac{\Delta E}{t}$, $P = \vec{F}\vec{v}$), including but not limited to:
  - uniformly accelerated rectilinear motion
  - objects raised against the force of gravity
  - work done against air resistance, rolling resistance and friction

Momentum, Energy and Simple Systems

Inquiry question: How is the motion of objects in a simple system dependent on the interaction between the objects?

Students:

- conduct an investigation to describe and analyse one-dimensional (collinear) and two-dimensional interactions of objects in simple closed systems (ACSPH064)
- analyse quantitatively and predict, using the law of conservation of momentum ($\Sigma m\vec{v}_{before} = \Sigma m\vec{v}_{after}$) and, where appropriate, conservation of kinetic energy ($\Sigma \frac{1}{2} m\vec{v}^2_{before} = \Sigma \frac{1}{2} m\vec{v}^2_{after}$), the results of interactions in elastic collisions (ACSPH066) 8.4.3/8.4.4
- investigate the relationship and analyse information obtained from graphical representations of force as a function of time
- evaluate the effects of forces involved in collisions and other interactions, and analyse quantitatively the interactions using the concept of impulse ($\Delta\vec{p} = \vec{F}\Delta t$)
- analyse and compare the momentum and kinetic energy of elastic and inelastic collisions (ACSPH066) 8.4.3/8.4.4

Module 3: Waves and Thermodynamics

Outcomes

A student:

- conducts investigations to collect valid and reliable primary and secondary data and information PH11/12-3
- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4
- solves scientific problems using primary and secondary data, critical thinking skills and scientific processes PH11/12-6
- communicates scientific understanding using suitable language and terminology for a specific audience or purpose PH11/12-7
- explains and analyses waves and the transfer of energy by sound, light and thermodynamic principles PH11-10

Content Focus

Wave motion involves the transfer of energy without the transfer of matter. By exploring the behaviour of wave motion and examining the characteristics of wavelength, frequency, period, velocity and amplitude, students further their understanding of the properties of waves. They are then able to demonstrate how waves can be reflected, refracted, diffracted and superposed (interfered) and to develop an understanding that not all waves require a medium for their propagation. Students examine mechanical waves and electromagnetic waves, including their similarities and differences.

Students also examine energy and its transfer, in the form of heat, from one place to another. Thermodynamics is the study of the relationship between energy, work, temperature and matter. Understanding this relationship allows students to appreciate particle motion within objects. Students have the opportunity to examine how hot objects lose energy in three ways: first, by conduction, and, second, by convection – which both involve the motion of particles; and, third, the emission of electromagnetic radiation. An understanding of thermodynamics is a pathway to understanding related concepts in many fields involving Science, Technology, Engineering and Mathematics (STEM).

Working Scientifically

In this module, students focus on conducting investigations, collecting and processing data and information, interpreting trends in data and communicating scientific ideas about waves and thermodynamics. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Wave Properties

Inquiry question: What are the properties of all waves and wave motion?

Students:

- conduct a practical investigation involving the creation of mechanical waves in a variety of situations in order to explain:
  - the role of the medium in the propagation of mechanical waves
  - the transfer of energy involved in the propagation of mechanical waves (ACSPH067, ACSPH070) 8.2.1
- conduct practical investigations to explain and analyse the differences between:
  - transverse and longitudinal waves (ACSPH068)
  - mechanical and electromagnetic waves (ACSPH070, ACSPH074)
- construct and/or interpret graphs of displacement as a function of time and as a function of position of transverse and longitudinal waves, and relate the features of those graphs to the following wave characteristics:
  - velocity
  - frequency
  - period
  - wavelength
  - wave number 8.2.1
  - displacement and amplitude (ACSPH069)
- solve problems and/or make predictions by modelling and applying the following relationships to a variety of situations:
  - $v = f\lambda$
  - $f = \frac{1}{T}$
  - $k = \frac{2\pi}{\lambda}$ 8.2.1

Wave Behaviour

Inquiry question: How do waves behave?

Students:

- explain the behaviour of waves in a variety of situations by investigating the phenomena of:
  - reflection
  - refraction
  - diffraction 8.2.2/8.2.3
  - wave superposition (ACSPH071, ACSPH072)
- conduct an investigation to distinguish between progressive and standing waves (ACSPH072)
- conduct an investigation to explore resonance in mechanical systems and the relationships between:
  - driving frequency
  - natural frequency of the oscillating system
  - amplitude of motion
  - transfer/transformation of energy within the system (ACSPH073)

Sound Waves

Inquiry question: What evidence suggests that sound is a mechanical wave?

Students:

8.2.2

- conduct a practical investigation to relate the pitch and loudness of a sound to its wave characteristics
- model the behaviour of sound in air as a longitudinal wave *8.2.2*
- relate the displacement of air molecules to variations in pressure (ACSPH070) *8.2.3 previously focused on just light*
- investigate quantitatively the relationship between distance and intensity of sound
- conduct investigations to analyse the reflection, diffraction, resonance and superposition of sound waves (ACSPH071)
- investigate and model the behaviour of standing waves on strings and/or in pipes to relate quantitatively the fundamental and harmonic frequencies of the waves that are produced to the physical characteristics (eg length, mass, tension, wave velocity) of the medium (ACSPH072)
- analyse qualitatively and quantitatively the relationships of the wave nature of sound to explain:
  - beats ($f_{beat} = |f_2 - f_1|$)
  - the Doppler effect $f' = f\frac{(v_{wave}+v_{observer})}{(v_{wave}-v_{source})}$

Ray Model of Light

Inquiry question: What properties can be demonstrated when using the ray model of light?

Students:

- conduct a practical investigation to analyse the formation of images in mirrors and lenses via reflection and refraction using the ray model of light (ACSPH075)
- conduct investigations to examine qualitatively and quantitatively the refraction and total internal reflection of light (ACSPH075, ACSPH076) *8.2.4*
- predict quantitatively, using Snell's Law, the refraction and total internal reflection of light in a variety of situations
- conduct a practical investigation to demonstrate and explain the phenomenon of the dispersion of light
- conduct an investigation to demonstrate the relationship between inverse square law, the intensity of light and the transfer of energy (ACSPH077) *8.2.3*
- solve problems or make quantitative predictions in a variety of situations by applying the following relationships to:
  - $n_x = \frac{c}{v_x}$ – for the refractive index of medium x, v_x is the speed of light in the medium *8.2.3*
  - $n_1 sin\,(i) = n_2 sin\,(r)$ (Snell's Law) *→ new formulation, current syllabus is $\frac{v_1}{v_2} = \frac{\sin(i)}{\sin(r)}$*
  - $sin\,(i_c) = \frac{1}{n_x}$ – for the critical angle i_c of medium x
  - $I_1 r_1^2 = I_2 r_2^2$ – to compare the intensity of light at two points, r_1 and r_2

Thermodynamics

Inquiry question: How are temperature, thermal energy and particle motion related?

Students:

- explain the relationship between the temperature of an object and the kinetic energy of the particles within it (ACSPH018)
- explain the concept of thermal equilibrium (ACSPH022)
- analyse the relationship between the change in temperature of an object and its specific heat capacity through the equation $\Delta Q = mc\Delta T$ (ACSPH020)

- investigate energy transfer by the process of:
  - conduction
  - convection
  - radiation (ACSPH016)
- conduct an investigation to analyse qualitatively and quantitatively the latent heat involved in a change of state
- model and predict quantitatively energy transfer from hot objects by the process of thermal conductivity
- apply the following relationships to solve problems and make quantitative predictions in a variety of situations:
  - $\Delta Q = mc\Delta T$, where c is the specific heat capacity of a substance
  - $\frac{Q}{t} = \frac{kA\Delta T}{d}$, where k is the thermal conductivity of a material

Module 4: Electricity and Magnetism

Outcomes

A student:

› develops and evaluates questions and hypotheses for scientific investigation PH11/12-1
› analyses and evaluates primary and secondary data and information PH11/12-5
› communicates scientific understanding using suitable language and terminology for a specific audience or purpose PH11/12-7
› explains and quantitatively analyses electric fields, circuitry and magnetism PH11-11

Content Focus

Atomic theory and the laws of conservation of energy and electric charge are unifying concepts in understanding the electrical and magnetic properties and behaviour of matter. Interactions resulting from these properties and behaviour can be understood and analysed in terms of electric fields represented by lines. Students use these representations and mathematical models to make predictions about the behaviour of objects, and explore the limitations of the models.

Students also examine how the analysis of electrical circuits' behaviour and the transfer and conversion of energy in electrical circuits has led to a variety of technological applications.

Working Scientifically

In this module, students focus on developing questions and hypotheses, processing and analysing trends and patterns in data, and communicating ideas about electricity and magnetism. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Electrostatics

Inquiry question: How do charged objects interact with other charged objects and with neutral objects?

Students:

- conduct investigations to describe and analyse qualitatively and quantitatively:
  - processes by which objects become electrically charged (ACSPH002)
  - the forces produced by other objects as a result of their interactions with charged objects (ACSPH103)
  - variables that affect electrostatic forces between those objects (ACSPH103)
- using the electric field lines representation, model qualitatively the direction and strength of electric fields produced by:
  - simple point charges
  - pairs of charges
  - dipoles 8.3.2
  - parallel charged plates

- apply the electric field model to account for and quantitatively analyse interactions between charged objects using:
  - $\vec{E} = \frac{\vec{F}}{q}$ (ACSPH103, ACSPH104)
  - $\vec{E} = -\frac{V}{d}$
  - $\vec{F} = \frac{1}{4\pi\varepsilon_0} \times \frac{q_1 q_2}{r^2}$ (ACSPH102) 8.3.2/9.4.2
- analyse the effects of a moving charge in an electric field, in order to relate potential energy, work and equipotential lines, by applying: (ACSPH105)
  - $V = \frac{\Delta U}{q}$, where U is potential energy and q is the charge

Electric Circuits

Inquiry question: How do the processes of the transfer and the transformation of energy occur in electric circuits?

Students:

- investigate the flow of electric current in metals and apply models to represent current, including: 8.3.2
  - $I = \frac{q}{t}$ (ACSPH038)
- investigate quantitatively the current–voltage relationships in ohmic and non-ohmic resistors to explore the usefulness and limitations of Ohm's Law using: 8.3.2
  - $V = \frac{W}{q}$
  - $R = \frac{V}{I}$ (ACSPH003, ACSPH041, ACSPH043)
- investigate quantitatively and analyse the rate of conversion of electrical energy in components of electric circuits, including the production of heat and light, by applying $P = VI$ and $E = Pt$ and variations that involve Ohm's Law (ACSPH042)
- investigate qualitatively and quantitatively series and parallel circuits to relate the flow of current through the individual components, the potential differences across those components and the rate of energy conversion by the components to the laws of conservation of charge and energy, by deriving the following relationships: (ACSPH038, ACSPH039, ACSPH044)

extension of 8.3.3

  - $\Sigma I = 0$ (Kirchoff's current law – conservation of charge)
  - $\Sigma V = 0$ (Kirchoff's voltage law – conservation of energy)
  - $R_{Series} = R_1 + R_2 + \ldots + R_n$
  - $\frac{1}{R_{Parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$
- investigate quantitatively the application of the law of conservation of energy to the heating effects of electric currents, including the application of $P = VI$ and variations of this involving Ohm's Law (ACSPH043)

Magnetism

Inquiry question: How do magnetised and magnetic objects interact?

Students:

- investigate and describe qualitatively the force produced between magnetised and magnetic materials in the context of ferromagnetic materials (ACSPH079)
- use magnetic field lines to model qualitatively the direction and strength of magnetic fields produced by magnets, current-carrying wires and solenoids and relate these fields to their effect on magnetic materials that are placed within them (ACSPH083) 8.3.5

- conduct investigations into and describe quantitatively the magnetic fields produced by wires and solenoids, including: (ACSPH106, ACSPH107)
  - $B = \frac{\mu_0 I}{2\pi r}$
  - $B = \frac{\mu_0 N I}{L}$
- investigate and explain the process by which ferromagnetic materials become magnetised (ACSPH083)
- apply models to represent qualitatively and describe quantitatively the features of magnetic fields

Module 5: Advanced Mechanics

Outcomes

A student:

› selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4

› analyses and evaluates primary and secondary data and information PH11/12-5

› solves scientific problems using primary and secondary data, critical thinking skills and scientific processes PH11/12-6

› communicates scientific understanding using suitable language and terminology for a specific audience or purpose PH11/12-7

› describes and analyses qualitatively and quantitatively circular motion and motion in a gravitational field, in particular, the projectile motion of particles PH12-12

Content Focus

Motion in one dimension at constant velocity or constant acceleration can be explained and analysed relatively simply. However, motion is frequently more complicated because objects move in two or three dimensions, causing the net force to vary in size or direction.

Students develop an understanding that all forms of complex motion can be understood by analysing the forces acting on a system, including the energy transformations taking place within and around the system. By applying new mathematical techniques, students model and predict the motion of objects within systems. They examine two-dimensional motion, including projectile motion and uniform circular motion, along with the orbital motion of planets and satellites, which are modelled as an approximation to uniform circular motion.

Working Scientifically

In this module, students focus on gathering, analysing and evaluating data to solve problems and communicate ideas about advanced mechanics. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Projectile Motion

Inquiry question: How can models that are used to explain projectile motion be used to analyse and make predictions?

Students:

- analyse the motion of projectiles by resolving the motion into horizontal and vertical components, making the following assumptions:
  - a constant vertical acceleration due to gravity
  - zero air resistance

explicit assumptions

- apply the modelling of projectile motion to quantitatively derive the relationships between the following variables:
  - initial velocity
  - launch angle
  - maximum height
  - time of flight
  - final velocity
  - launch height
  - horizontal range of the projectile (ACSPH099)

additions to 9.2.2

- conduct a practical investigation to collect primary data in order to validate the relationships derived above.
- solve problems, create models and make quantitative predictions by applying the equations of motion relationships for uniformly accelerated and constant rectilinear motion

Circular Motion

Inquiry question: Why do objects move in circles?

8.4.2 | 9.2.2

Students:

- conduct investigations to explain and evaluate, for objects executing uniform circular motion, the relationships that exist between:
  - centripetal force
  - mass
  - speed
  - radius
- analyse the forces acting on an object executing uniform circular motion in a variety of situations, for example:
  - cars moving around horizontal circular bends
  - a mass on a string
  - objects on banked tracks (ACSPH100)]-9.2.2
- solve problems, model and make quantitative predictions about objects executing uniform circular motion in a variety of situations, using the following relationships:
  - $\vec{a} = \frac{|\vec{v}|^2}{r}$
  - $\Sigma\vec{F} = \frac{m|\vec{v}|^2}{r}$ 8.4.2 | 9.2.2
  - $\omega = \frac{\Delta\theta}{t}$
- investigate the relationship between the total energy and work done on an object executing uniform circular motion
- investigate the relationship between the rotation of mechanical systems and the applied torque ($\tau = \vec{r}\vec{F}_{\perp} = |\vec{r}||\vec{F}|\sin\theta$)

Motion in Gravitational Fields

Inquiry question: How does the force of gravity determine the motion of planets and satellites?

Students:

- apply qualitatively and quantitatively Newton's Law of Universal Gravitation to:
  - determine the force of gravity between two objects ($\vec{F} = -\frac{GMm}{r^2}$) ← old definition was $F = \frac{GmM}{r^2}$
  - investigate the factors that affect the gravitational field strength ($\vec{g} = \frac{GM}{r^2}$)
  - predict the gravitational field strength at any point in a gravitational field, including at the surface of a planet (ACSPH094, ACSPH095, ACSPH097)

- investigate the orbital motion of planets and artificial satellites when applying the relationships between the following quantities:
  - gravitational force
  - centripetal force
  - centripetal acceleration
  - mass
  - orbital radius
  - orbital velocity
  - orbital period
- predict quantitatively the orbital properties of planets and satellites in a variety of situations, including near the Earth and geostationary orbits, and relate these to their uses (ACSPH101)
- investigate the relationship of Kepler's Laws of Planetary Motion to the forces acting on, and the total energy of, planets in circular and non-circular orbits using: (ACSPH101)]9.2.2
  - $v_o = \frac{2\pi r}{T}$
  - $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$
- derive quantitatively and apply the concepts of gravitational force and gravitational potential energy in radial gravitational fields to a variety of situations, including but not limited to:
  - the concept of escape velocity ($v_{esc} = \sqrt{\frac{2GM}{r}}$)
  - total potential energy of a planet or satellite in its orbit ($U = -\frac{GMm}{r}$)
  - total energy of a planet or satellite in its orbit ($E = -\frac{GMm}{2r}$)
  - energy changes that occur when satellites move between orbits (ACSPH096)
  - Kepler's Laws of Planetary Motion (ACSPH101)

9.2.1 | 9.2.2 | 9.2.3

Module 6: Electromagnetism

Outcomes

A student:

- develops and evaluates questions and hypotheses for scientific investigation PH11/12-1
- designs and evaluates investigations in order to obtain primary and secondary data and information PH11/12-2
- conducts investigations to collect valid and reliable primary and secondary data and information PH11/12-3
- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4
- analyses and evaluates primary and secondary data and information PH11/12-5
- explains and analyses the electric and magnetic interactions due to charged particles and currents and evaluates their effect both qualitatively and quantitatively PH12-13

Content Focus

Discoveries about the interactions that take place between charged particles and electric and magnetic fields not only produced significant advances in physics, but also led to significant technological developments. These developments include the generation and distribution of electricity, and the invention of numerous devices that convert electrical energy into other forms of energy.

Understanding the similarities and differences in the interactions of single charges in electric and magnetic fields provides students with a conceptual foundation for this module. Phenomena that include the force produced on a current-carrying wire in a magnetic field, the force between current-carrying wires, Faraday's Law of Electromagnetic Induction, the principles of transformers and the workings of motors and generators can all be understood as instances of forces acting on moving charged particles in magnetic fields.

The law of conservation of energy underpins all of these interactions. The conversion of energy into forms other than the intended form is a problem that constantly drives engineers to improve designs of electromagnetic devices.

Working Scientifically

In this module, students focus on developing and evaluating questions and hypotheses when designing and conducting investigations; and obtaining data and information to solve problems about electromagnetism. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Charged Particles, Conductors and Electric and Magnetic Fields

Inquiry question: What happens to stationary and moving charged particles when they interact with an electric or magnetic field?

Students:

- investigate and quantitatively derive and analyse the interaction between charged particles and uniform electric fields, including: (ACSPH083)
  - electric field between parallel charged plates $\left(|\vec{E}| = -\frac{V}{d}\right)$
  - acceleration of charged particles by the electric field $(\vec{F} = m\vec{a}, \vec{F} = q\vec{E})$ – 9.4.2
  - work done on the charge $(W = qV, W = qEd, K = \frac{1}{2}mv^2)$
- model qualitatively and quantitatively the trajectories of charged particles in electric fields and compare them with the trajectories of projectiles in a gravitational field
- analyse the interaction between charged particles and uniform magnetic fields, including: (ACSPH083)
  - acceleration, perpendicular to the field, of charged particles – 9.4.2
  - the force on the charge $(\vec{F} = q\vec{v}\vec{B}sin\theta)$
- compare the interaction of charged particles moving in magnetic fields to:
  - the interaction of charged particles with electric fields
  - other examples of uniform circular motion (ACSPH108) – 8.3.2/9.4.2

The Motor Effect

Inquiry question: Under what circumstances is a force produced on a current-carrying conductor in a magnetic field?

Students:

- investigate qualitatively and quantitatively the interaction between a current-carrying conductor and a uniform magnetic field $(\vec{F} = \vec{B}I\vec{l}sin\theta)$ to establish: (ACSPH080, ACSPH081)
  - conditions under which the maximum force is produced
  - the relationship between the directions of the force, magnetic field strength and current – 9.3.1
  - conditions under which no force is produced on the conductor
- conduct a quantitative investigation to demonstrate the interaction between two parallel current-carrying wires
- analyse the interaction between two parallel current-carrying wires $\left(\frac{F}{l} = \frac{\mu_0}{2\pi} \times \frac{I_1 I_2}{r}\right)$ and determine the relationship between the International System of Units (SI) definition of an ampere and Newton's Third Law of Motion (ACSPH081, ACSPH106)

Electromagnetic Induction

Inquiry question: How are electric and magnetic fields related?

Students:

- describe how magnetic flux can change, with reference to the relationship $\Phi = BA$ (ACSPH083, ACSPH107, ACSPH109)
- analyse qualitatively and quantitatively, with reference to energy transfers and transformations, examples of Faraday's Law and Lenz's Law $\left(\varepsilon = -N\frac{\Delta\Phi}{\Delta t}\right)$, including but not limited to: (ACSPH081, ACSPH110)
  - the generation of an electromotive force (emf) and evidence for Lenz's Law produced by the relative movement between a magnet, straight conductors, metal plates and solenoids
  - the generation of an emf produced by the relative movement or changes in current in one solenoid in the vicinity of another solenoid
- analyse quantitatively the operation of ideal transformers through the application of: (ACSPH110)
  - $\frac{V_P}{V_S} = \frac{N_P}{N_S}$
  - $V_p I_p = V_s I_s$
- evaluate qualitatively the limitations of the ideal transformer model and the strategies used to improve transformer efficiency, including but not limited to:
  - incomplete flux linkage
  - resistive heat production and eddy currents
- analyse applications of step-up and step-down transformers, including but not limited to:
  - the distribution of energy using high-voltage transmission lines

Applications of the Motor Effect

Inquiry question: How has knowledge about the Motor Effect been applied to technological advances?

Students:

- investigate the operation of a simple DC motor to analyse:
  - the functions of its components
  - production of a torque ($\vec{\tau} = nBIA\cos\theta$)
  - effects of back emf (ACSPH108)
- analyse the operation of simple DC and AC generators and AC induction motors (ACSPH110)
- relate Lenz's Law to the law of conservation of energy and apply the law of conservation of energy to:
  - DC motors and
  - magnetic braking

Module 7: The Nature of Light

Outcomes

A student:

› develops and evaluates questions and hypotheses for scientific investigation PH11/12-1
› designs and evaluates investigations in order to obtain primary and secondary data and information PH11/12-2
› conducts investigations to collect valid and reliable primary and secondary data and information PH11/12-3
› selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media PH11/12-4
› communicates scientific understanding using suitable language and terminology for a specific audience or purpose PH11/12-7
› describes and analyses evidence for the properties of light and evaluates the implications of this evidence for modern theories of physics in the contemporary world PH12-14

Content Focus

Prior to the 20th century, physicists, including Newton and Maxwell, developed theories and models about mechanics, electricity and magnetism and the nature of matter. These theories and models had great explanatory power and produced useful predictions. However, the 20th century saw major developments in physics as existing theories and models were challenged by new observations that could not be explained. These observations led to the development of quantum theory and the theory of relativity. Technologies arising from these theories have shaped the modern world. For example, the independence of the speed of light on the frame of observation or the motion of the source and observer had significant consequences for the measurement, and concepts about the nature, of time and space.

Throughout this module, students explore the evidence supporting these physical theories, along with the power of scientific theories to make useful predictions.

Working Scientifically

In this module, students focus on developing and evaluating questions and hypotheses when designing and conducting investigations; evaluating the data obtained from investigations; and communicating ideas about the nature of light. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Electromagnetic Spectrum

Inquiry question: What is light?

Students:

- investigate Maxwell's contribution to the classical theory of electromagnetism, including:
  - unification of electricity and magnetism
  - prediction of electromagnetic waves
  - prediction of velocity (ACSPH113)

- describe the production and propagation of electromagnetic waves and relate these processes qualitatively to the predictions made by Maxwell's electromagnetic theory (ACSPH112, ACSPH113)
- conduct investigations of historical and contemporary methods used to determine the speed of light and its current relationship to the measurement of time and distance (ACSPH082)
- conduct an investigation to examine a variety of spectra produced by discharge tubes, reflected sunlight or incandescent filaments
- investigate how spectroscopy can be used to provide information about:
  - the identification of elements
- investigate how the spectra of stars can provide information on:
  - surface temperature
  - rotational and translational velocity
  - density
  - chemical composition

Light: Wave Model

Inquiry question: What evidence supports the classical wave model of light and what predictions can be made using this model?

Students:

- conduct investigations to analyse qualitatively the diffraction of light (ACSPH048, ACSPH076)
- conduct investigations to analyse quantitatively the interference of light using double slit apparatus and diffraction gratings ($d\sin\theta = m\lambda$) (ACSPH116, ACSPH117, ACSPH140)
- analyse the experimental evidence that supported the models of light that were proposed by Newton and Huygens (ACSPH050, ACSPH118, ACSPH123)
- conduct investigations quantitatively using the relationship of Malus's Law ($I = I_{max}\cos^2\theta$) for plane polarisation of light, to evaluate the significance of polarisation in developing a model for light (ACSPH050, ACSPH076, ACSPH120)

Light: Quantum Model

Inquiry question: What evidence supports the particle model of light and what are the implications of this evidence for the development of the quantum model of light?

Students:

- analyse the experimental evidence gathered about black body radiation, including Wein's Law $\left(\lambda_{max} = \frac{b}{T}\right)$ related to Planck's contribution to a changed model of light (ACSPH137)
- investigate the evidence from photoelectric effect investigations that demonstrated inconsistency with the wave model for light (ACSPH087, ACSPH123, ACSPH137)
- analyse the photoelectric effect ($E_k = hf - \Phi$) as it occurs in metallic elements by applying the law of conservation of energy and the photon model of light, (ACSPH119)

Light and special relativity

Inquiry question: How does the behaviour of light affect concepts of time, space and matter?

Students:

- analyse and evaluate the evidence confirming or denying Einstein's two postulates:
  - the speed of light in a vacuum is an absolute constant
  - all inertial frames of reference are equivalent (ACSPH131)
- investigate the evidence, from Einstein's thought experiments and subsequent experimental validation, for time dilation $\left(t = \frac{t_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}\right)$ and length contraction $\left(l = l_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}\right)$, and analyse quantitatively situations in which these are observed, for example:
  - observations of cosmic-origin muons at the Earth's surface
  - atomic clocks (Hafele–Keating experiment)
  - evidence from particle accelerators
  - evidence from cosmological studies
- describe the consequences and applications of relativistic momentum with reference to:
  - $p_v = \frac{mv}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$
  - the limitation on the maximum velocity of a particle imposed by special relativity (ACSPH133)
- Use Einstein's mass–energy equivalence relationship ($E = mc^2$) to calculate the energy released by processes in which mass is converted to energy, for example: (ACSPH134)
  - production of energy by the sun
  - particle–antiparticle interactions, eg positron–electron annihilation
  - combustion of conventional fuel

Module 8: From the Universe to the Atom

Outcomes

A student:

- analyses and evaluates primary and secondary data and information PH11/12-5
- solves scientific problems using primary and secondary data, critical thinking skills and scientific processes PH11/12-6
- communicates scientific understanding using suitable language and terminology for a specific audience or purpose PH11/12-7
- explains and analyses the evidence supporting the relationship between astronomical events and the nucleosynthesis of atoms and relates these to the development of the current model of the atom PH12-15

Content Focus

Humans have always been fascinated with the finite or infinite state of the Universe and whether there ever was a beginning to time. Where does all the matter that makes up the Universe come from? Ideas and theories about the beginnings of the Universe, based on sound scientific evidence, have come and gone. Current theories such as the Big Bang theory and claims of an expanding Universe are based on scientific evidence available today through investigations that use modern technologies. Evidence gathered on the nucleosynthesis reactions in stars allows scientists to understand how elements are made in the nuclear furnace of stars. On scales as large as the Universe to those as small as an atom, humans look to the sky for answers through astronomical observations of stars and galaxies.

Beginning in the late 19th and early 20th centuries, experimental discoveries revolutionised the accepted understanding of the nature of matter on an atomic scale. Observations of the properties of matter and light inspired the development of better models of matter, which in turn have been modified or abandoned in the light of further experimental investigations.

By studying the development of the atomic models through the work of Thomson and Rutherford, who established the nuclear model of the atom – a positive nucleus surrounded by electrons – students further their understanding of the limitations of theories and models. The work of Bohr, de Broglie and, later, Schrödinger demonstrated that the quantum mechanical nature of matter was a better way to understand the structure of the atom. Experimental investigations of the nucleus have led to an understanding of radioactive decay, the ability to extract energy from nuclear fission and fusion, and a deeper understanding of the atomic model.

Particle accelerators have revealed that protons themselves are not fundamental, and have continued to provide evidence in support of the Standard Model of matter. In studying this module, students can appreciate that the fundamental particle model is forever being updated and that our understanding of the nature of matter remains incomplete.

Working Scientifically

In this module, students focus on analysing and evaluating data to solve problems and communicate scientific understanding about the development of the atomic model and the origins of the Universe. Students should be provided with opportunities to engage with all the Working Scientifically skills throughout the course.

Content

Origins of the Elements

Inquiry question: What evidence is there for the origins of the elements?

Students:

- investigate the processes that led to the transformation of radiation into matter that followed the 'Big Bang'
- investigate the evidence that led to the discovery of the expansion of the Universe by Hubble (ACSPH138)
- analyse and apply Einstein's description of the equivalence of energy and mass and relate this to the nuclear reactions that occur in stars (ACSPH031)
- account for the production of emission and absorption spectra and compare these with a continuous black body spectrum (ACSPH137)
- investigate the key features of stellar spectra and describe how these are used to classify stars
- investigate the Hertzsprung–Russell diagram and how it can be used to determine the following about a star:
  - characteristics and evolutionary stage
  - surface temperature
  - colour
  - luminosity
- investigate the types of nucleosynthesis reactions involved in Main Sequence and Post-Main Sequence stars, including but not limited to:
  - proton–proton chain
  - CNO (carbon–nitrogen–oxygen) cycle

Structure of the Atom

Inquiry question: How is it known that atoms are made up of protons, neutrons and electrons?

Students:

- investigate, assess and model the experimental evidence supporting the existence and properties of the electron, including:
  - early experiments examining the nature of cathode rays
  - Thomson's charge-to-mass experiment
  - Millikan's oil drop experiment (ACSPH026)
- investigate, assess and model the experimental evidence supporting the nuclear model of the atom, including:
  - the Geiger–Marsden experiment
  - Rutherford's atomic model
  - Chadwick's discovery of the neutron (ACSPH026)

Quantum Mechanical Nature of the Atom

Inquiry question: How is it known that classical physics cannot explain the properties of the atom?

Students:

Quanta 9.8.1

- assess the limitations of the Rutherford and Bohr atomic models
- investigate the line emission spectra to examine the Balmer series in hydrogen (ACSPH138)
- relate qualitatively and quantitatively the quantised energy levels of the hydrogen atom and the law of conservation of energy to the line emission spectrum of hydrogen using:
  - $E = hf$ *← I2I 9.4.2*
  - $E = \frac{hc}{\lambda}$
  - $\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$ (ACSPH136)

Quanta 9.8.2

- investigate de Broglie's matter waves, and the experimental evidence that developed the following formula:
  - $\lambda = \frac{h}{mv}$ (ACSPH140)
- analyse the contribution of Schrödinger to the current model of the atom

Properties of the Nucleus

Inquiry question: How can the energy of the atomic nucleus be harnessed?

Students:

Medical 9.6.3
Cosmic 8.5.4
Quanta 9.8.3

- analyse the spontaneous decay of unstable nuclei, and the properties of the alpha, beta and gamma radiation emitted (ACSPH028, ACSPH030)

Medical 9.6.3

- examine the model of half-life in radioactive decay and make quantitative predictions about the activity or amount of a radioactive sample using the following relationships:
  - $N_t = N_o e^{-\lambda t}$
  - $\lambda = \frac{\ln(2)}{t_{1/2}}$

  where N_t = number of particles at time t, N_o = number of particles present at $t = 0$, λ = decay constant, $t_{1/2}$ = time for half the radioactive amount to decay (ACSPH029)

Quanta 9.8.3
9.8.4

- model and explain the process of nuclear fission, including the concepts of controlled and uncontrolled chain reactions, and account for the release of energy in the process (ACSPH033, ACSPH034)

Quanta 9.8.3
Astro 9.7.6

- analyse relationships that represent conservation of mass-energy in spontaneous and artificial nuclear transmutations, including alpha decay, beta decay, nuclear fission and nuclear fusion (ACSPH032)
- account for the release of energy in the process of nuclear fusion (ACSPH035, ACSPH036)

Quanta 9.8.3

- predict quantitatively the energy released in nuclear decays or transmutations, including nuclear fission and nuclear fusion, by applying: (ACSPH031, ACSPH035, ACSPH036)
  - the law of conservation of energy
  - mass defect
  - binding energy
  - Einstein's mass–energy equivalence relationship ($E = mc^2$)

9.2.4 Space

Deep inside the Atom

Inquiry question: How is it known that human understanding of matter is still incomplete?

Students:

Quanta 9.8.4

- analyse the evidence that suggests:
  - that protons and neutrons are not fundamental particles
  - the existence of subatomic particles other than protons, neutrons and electrons
- investigate the Standard Model of matter, including:
  - quarks, and the quark composition hadrons
  - leptons
  - fundamental forces (ACSPH141, ACSPH142)
- investigate the operation and role of particle accelerators in obtaining evidence that tests and/or validates aspects of theories, including the Standard Model of matter (ACSPH120, ACSPH121, ACSPH122, ACSPH146)