Unit 1: What ideas explain the physical world?

Ideas in physics are dynamic. As physicists explore concepts, theories evolve. Often this requires the detection, description and explanation of things that cannot be seen. In this unit students explore how physics explains phenomena, at various scales, which are not always visible to the unaided human eye. They examine some of the fundamental ideas and models used by physicists in an attempt to understand and explain the world. Students consider thermal concepts by investigating heat, probe common analogies used to explain electricity and consider the origins and formation of matter.

Students use thermodynamic principles to explain phenomena related to changes in thermal energy. They apply thermal laws when investigating energy transfers within and between systems, and assess the impact of human use of energy on the environment. Students examine the motion of electrons and explain how it can be manipulated and utilised. They explore current scientifically accepted theories that explain how matter and energy have changed since the origins of the Universe.

Students undertake quantitative investigations involving at least one independent, continuous variable.

Area of Study 1

How can thermal effects be explained?

In this area of study students investigate the thermodynamic principles related to heating processes, including concepts of temperature, energy and work. Students examine the environmental impacts of Earth's thermal systems and human activities with reference to the effects on surface materials, the emission of greenhouse gases and the contribution to the enhanced greenhouse effect. They analyse the strengths and limitations of the collection and interpretation of thermal data in order to consider debates related to climate science.

Outcome 1

On completion of this unit the student should be able to apply thermodynamic principles to analyse, interpret and explain changes in thermal energy in selected contexts, and describe the environmental impact of human activities with reference to thermal effects and climate science concepts.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on pages 11 and 12 of the study design.

Key knowledge

Thermodynamics principles

- convert temperature between degrees Celsius and kelvin
- describe the Zeroth Law of Thermodynamics as two bodies in contact with each other coming to a thermal equilibrium
- describe temperature with reference to the average kinetic energy of the atoms and molecules within a system
- investigate and apply theoretically and practically the First Law of Thermodynamics to simple situations: $Q = U + W$
- explain internal energy as the energy associated with random disordered motion of molecules
- distinguish between conduction, convection and radiation with reference to heat transfers within and between systems

- investigate and analyse theoretically and practically the energy required to:
  - raise the temperature of a substance: $Q = mc\Delta T$
  - change the state of a substance: $Q = mL$
- explain why cooling results from evaporation using a simple kinetic energy model.

Thermodynamics and climate science

- identify regions of the electromagnetic spectrum as radio, microwave, infrared, visible, ultraviolet, x-ray and gamma waves
- describe electromagnetic radiation emitted from the Sun as mainly ultraviolet, visible and infrared
- calculate the peak wavelength of the re-radiated electromagnetic radiation from Earth using Wien's Law: $\lambda_{max}T = \text{constant}$
- compare the total energy across the electromagnetic spectrum emitted by objects at different temperatures such as the Sun
- describe power radiated by a body as being dependent on the temperature of the body according to the Stefan-Boltzmann Law, $P \propto T^4$
- explain the roles of conduction, convection and radiation in moving heat around in Earth's mantle (tectonic movement) and atmosphere (weather)
- model the greenhouse effect as the flow and retention of thermal energy from the Sun, Earth's surface and Earth's atmosphere
- explain how greenhouse gases in the atmosphere (including methane, water and carbon dioxide) absorb and re-emit infrared radiation
- analyse changes in the thermal energy of the surface of Earth and of Earth's atmosphere
- analyse the evidence for the influence of human activity in creating an enhanced greenhouse effect, including affecting surface materials and the balance of gases in the atmosphere.

Issues related to thermodynamics

- apply thermodynamic principles to investigate at least one issue related to the environmental impacts of human activity with reference to the enhanced greenhouse effect:
  - proportion of national energy use due to heating and cooling of homes
  - comparison of the operation and efficiencies of domestic heating and cooling systems: heat pumps; resistive heaters; reverse-cycle air conditioners; evaporative coolers; solar hot water systems; and/or electrical resistive hot water systems
  - possibility of homes being built that do not require any active heating or cooling at all
  - use of thermal imaging and infrared thermography in locating heating losses in buildings and/or system malfunctions; cost savings implications
  - determination of the energy ratings of home appliances and fittings: insulation; double glazing; window size; light bulbs; and/or electrical gadgets, appliances or machines
  - cooking alternatives: appliance options (microwave, convection, induction); fuel options (gas, electricity, solar, fossil fuel)
  - automobile efficiencies: fuel options (diesel petrol, LPG and electric); air delivery options (naturally aspirated, supercharged and turbocharged); and fuel delivery options (common rail, direct injection and fuel injection)
- explain how concepts of reliability, validity and uncertainty relate to the collection, interpretation and communication of data related to thermodynamics and climate science.

Area of Study 2

How do electric circuits work?

Modelling is a useful tool in developing concepts that explain physical phenomena that cannot be directly observed. In this area of study students develop conceptual models to analyse electrical phenomena and undertake practical investigations of circuit components. Concepts of electrical safety are developed through the study of safety mechanisms and the effect of current on humans. Students apply and critically assess mathematical models during experimental investigations of DC circuits.

Outcome 2

On completion of this unit the student should be able to investigate and apply a basic DC circuit model to simple battery-operated devices and household electrical systems, apply mathematical models to analyse circuits, and describe the safe and effective use of electricity by individuals and the community.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on pages 11 and 12 of the study design.

Key knowledge

Concepts used to model electricity

- apply concepts of charge (Q), electric current (I), potential difference (V), energy (E) and power (P), in electric circuits
- explore different analogies used to describe electric current and potential difference
- investigate and analyse theoretically and practically electric circuits using the relationships:
  $I = \frac{Q}{t}$, $V = \frac{E}{Q}$, $P = \frac{E}{t} = VI$
- justify the use of selected meters (ammeter, voltmeter, multimeter) in circuits
- apply the kilowatt-hour (kW h) as a unit of energy.

Circuit electricity

- model resistance in series and parallel circuits using
  – current versus potential difference (I–V) graphs
  – resistance as the potential difference to current ratio, including R = constant for ohmic devices
  – equivalent effective resistance in arrangements in
    - series: $R_T = R_1 + R_2 + ... + R_n$ and
    - parallel: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_n}$
- calculate and analyse the effective resistance of circuits comprising parallel and series resistance and voltage dividers
- model household (AC) electrical systems as simple direct current (DC) circuits
- compare power transfers in series and parallel circuits
- explain why the circuits in homes are mostly parallel circuits.

Using electricity

- investigate and apply theoretically and practically concepts of current, resistance, potential difference (voltage drop) and power to the operation of electronic circuits comprising resistors, light bulbs, diodes, thermistors, light dependent resistors (LDRs), light-emitting diodes (LEDs) and potentiometers (quantitative analysis restricted to use of $I = \frac{V}{R}$ and $P = VI$)
- investigate practically the operation of simple circuits containing resistors, variable resistors, diodes and other non-ohmic devices
- describe energy transfers and transformations with reference to transducers.

Electrical safety

- model household electricity connections as a simple circuit comprising fuses, switches, circuit breakers, loads and earth
- compare the operation of safety devices including fuses, circuit breakers and residual current devices (RCDs)
- describe the causes, effects and treatment of electric shock in homes and identify the approximate danger thresholds for current and duration.

Area of Study 3

What is matter and how is it formed?

In this area of study students explore the nature of matter, and consider the origins of atoms, time and space. They examine the currently accepted theory of what constitutes the nucleus, the forces within the nucleus and how energy is derived from the nucleus.

Outcome 3

On completion of this unit the student should be able explain the origins of atoms, the nature of subatomic particles and how energy can be produced by atoms.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on pages 11 and 12 of the study design.

Key knowledge

Origins of atoms

- describe the Big Bang as a currently held theory that explains the origins of the Universe
- describe the origins of both time and space with reference to the Big Bang Theory
- explain the changing Universe over time due to expansion and cooling
- apply scientific notation to quantify and compare the large ranges of magnitudes of time, distance, temperature and mass considered when investigating the Universe
- explain the change of matter in the stages of the development of the Universe including inflation, elementary particle formation, annihilation of anti-matter and matter, commencement of nuclear fusion, cessation of fusion and the formation of atoms.

Particles in the nucleus

- explain nuclear stability with reference to the forces that operate over very small distances
- describe the radioactive decay of unstable nuclei with reference to half-life
- model radioactive decay as random decay with a particular half-life, including mathematical modelling with reference to whole half-lives
- apply a simple particle model of the atomic nucleus to explain the origin of α, β^-, β^+ and γ radiation, including changes to the number of nucleons
- explain nuclear transformations using decay equations involving α, β^-, β^+ and γ radiation
- analyse decay series diagrams with reference to type of decay and stability of isotopes
- relate predictions to the subsequent discoveries of the neutron, neutrino, positron and Higgs boson
- describe quarks as components of subatomic particles
- distinguish between the two types of forces holding the nucleus together: the strong nuclear force and the weak nuclear force
- compare the nature of leptons, hadrons, mesons and baryons
- explain that for every elementary matter particle there exists an antimatter particle of equal mass and opposite charge, and that if a particle and its antiparticle come into contact they will annihilate each other to create radiation.

Energy from the atom

- explain nuclear energy as energy resulting from the conversion of mass: $E = mc^2$
- compare the processes of nuclear fusion and nuclear fission
- explain, using a binding energy curve, why both fusion and fission are reactions that produce energy
- explain light as an electromagnetic wave that is produced by the acceleration of charges
- describe the production of synchrotron radiation by an electron radiating energy at a tangent to its circular path
- model the production of light as a result of electron transitions between energy levels within an atom.

Assessment

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study, including the key knowledge and key science skills listed for the outcomes, should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessments at Units 1 and 2 are school-based. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision.

For this unit students are required to demonstrate achievement of three outcomes. As a set these outcomes encompass all areas of study.

Suitable tasks for assessment may be selected from the following:

For Outcomes 1, 2 and 3

- an annotated folio of practical activities
- data analysis
- design, building, testing and evaluation of a device
- an explanation of the operation of a device

- a proposed solution to a scientific or technological problem
- a report of a selected physics phenomenon
- a modelling activity
- a media response
- a summary report of selected practical investigations
- a reflective learning journal/blog related to selected activities or in response to an issue
- a test comprising multiple choice and/or short answer and/or extended response.

Where teachers allow students to choose between tasks they must ensure that the tasks they set are of comparable scope and demand.

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations in each of Areas of Study 1 and 2 and to investigations in Area of Study 3 involving the use of secondary data and/or modelling.

Unit 2: What do experiments reveal about the physical world?

In this unit students explore the power of experiments in developing models and theories. They investigate a variety of phenomena by making their own observations and generating questions, which in turn lead to experiments. Students make direct observations of physics phenomena and examine the ways in which phenomena that may not be directly observable can be explored through indirect observations.

In the core component of this unit students investigate the ways in which forces are involved both in moving objects and in keeping objects stationary. Students choose one of twelve options related to astrobiology, astrophysics, bioelectricity, biomechanics, electronics, flight, medical physics, nuclear energy, nuclear physics, optics, sound and sports science. The option enables students to pursue an area of interest by investigating a selected question.

Students design and undertake investigations involving at least one independent, continuous variable. A student-designed practical investigation relates to content drawn from Area of Study 1 and/or Area of Study 2 and is undertaken in Area of Study 3.

Area of Study 1

How can motion be described and explained?

In this area of study students observe motion and explore the effects of balanced and unbalanced forces on motion. They analyse motion using concepts of energy, including energy transfers and transformations, and apply mathematical models during experimental investigations of motion. Students model how the mass of finite objects can be considered to be at a point called the centre of mass. They describe and analyse graphically, numerically and algebraically the motion of an object, using specific physics terminology and conventions.

Outcome 1

On completion of this unit the student should be able to investigate, analyse and mathematically model the motion of particles and bodies.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on pages 11 and 12 of the study design.

Key knowledge

Concepts used to model motion

- identify parameters of motion as vectors or scalars
- analyse graphically, numerically and algebraically, straight-line motion under constant acceleration:
  $v = u + at,\ v^2 = u^2 + 2as,\ s = \frac{1}{2}(u+v)t,\ s = ut + \frac{1}{2}at^2,\ s = vt - \frac{1}{2}at^2$
- graphically analyse non-uniform motion in a straight line
- apply concepts of momentum to linear motion: $p = mv$.

Forces and motion

- explain changes in momentum as being caused by a net force: $F_{net} = \frac{\Delta p}{\Delta t}$
- model the force due to gravity, F_g, as the force of gravity acting at the centre of mass of a body, $F_g = mg$, where g is the gravitational field strength ($9.8\ \mathrm{N\ kg^{-1}}$ near the surface of Earth)
- model forces as vectors acting at the point of application (with magnitude and direction), labelling these forces using the convention 'force on A by B' or $F_{\text{on A by B}} = -F_{\text{on B by A}}$
- apply Newton's three laws of motion to a body on which forces act: $a = \frac{F_{net}}{m}$, $F_{\text{on A by B}} = -F_{\text{on B by A}}$
- apply the vector model of forces, including vector addition and components of forces, to readily observable forces including the force due to gravity, friction and reaction forces
- calculate torque: $\tau = r_{\perp}F$
- investigate and analyse theoretically and practically translational forces and torques in simple structures that are in rotational equilibrium.

Energy and motion

- apply the concept of work done by a constant force using:
  - work done = constant force × distance moved in direction of force: $W = Fs$
  - work done = area under force-distance graph
- investigate and analyse theoretically and practically Hooke's Law for an ideal spring: $F = -k\Delta x$
- analyse and model mechanical energy transfers and transformations using energy conservation:
  - changes in gravitational potential energy near Earth's surface: $E_g = mg\Delta h$
  - potential energy in ideal springs: $E_s = \frac{1}{2}k\Delta x^2$
  - kinetic energy: $E_k = \frac{1}{2}mv^2$
- analyse rate of energy transfer using power: $P = \frac{E}{t}$
- calculate the efficiency of an energy transfer system: $\eta = \frac{\text{useful energy out}}{\text{total energy in}}$
- analyse impulse (momentum transfer) in an isolated system (for collisions between objects moving in a straight line): $I = \Delta p$
- investigate and analyse theoretically and practically momentum conservation in one dimension.

Area of Study 2

Options

Twelve options are available for selection in Area of Study 2. Each option is based on a different observation of the physical world. One option is to be selected by the student from the following:

- What are stars?
- Is there life beyond Earth's Solar System?
- How do forces act on the human body?
- How can AC electricity charge a DC device?
- How do heavy things fly?
- How do fusion and fission compare as viable nuclear energy power sources?
- How is radiation used to maintain human health?
- How do particle accelerators work?
- How can human vision be enhanced?

- How do instruments make music?
- How can performance in ball sports be improved?
- How does the human body use electricity?

Option 2.1: What are stars?

Observations of the night sky have changed over time from using just the naked eye to the use of sophisticated instruments. This option involves the examination of the birth, life and death of stars in the Universe. Students explore how the properties of starlight can provide information, including the star's distance from Earth, its temperature, composition, age and future.

Outcome 2.1

On completion of this unit the student should be able to apply concepts of light and nuclear physics to describe and explain the genesis and life cycle of stars, and describe the methods used to gather this information.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Astronomical measurement

- explain the use of electromagnetic radiation in collecting information about the Universe
- identify all electromagnetic waves as travelling at the same speed, c, in a vacuum
- calculate wavelength, frequency, period and speed of light: $c = f\lambda$, $T = \frac{1}{f}$
- identify spectroscopy as a tool to investigate the light from stars, and interpret and analyse spectroscopic data with reference to the properties of stars
- apply methods used for measurements of the distances to stars and galaxies (standard candles, parallax, red shift) to analyse secondary data.

Classification of stars

- describe the Sun as a typical star, including size, mass, energy output, colour and information obtained from the Sun's radiation spectrum
- identify the properties of stars, including luminosity, radius and mass, temperature and spectral type, and explain how these properties are used to classify stars
- explain nuclear fusion as the energy source of a star including: $E = mc^2$
- distinguish between the different nuclear fusion phenomena that occur in stars of various sizes.

Stellar life cycle

- apply the Hertzsprung–Russell diagram as a tool to describe the evolution and death of stars with differing initial mass
- relate the formation of stars to the formation of galaxies and planets
- describe future scenarios for a star, including white dwarfs, neutron stars and black holes
- explain the event horizon of a black hole and use $r_s = \frac{2GM}{c^2}$ to calculate the Schwarzschild radius
- describe the effects of the gravitational fields of black holes on space and time
- compare the Milky Way galaxy to other galaxies with different shape, colour or size
- explain and analyse how the chemical composition of stars and galaxies is used to determine their age
- investigate selected aspects of stellar life cycles by interpreting and applying appropriate data from relevant databases.

Option 2.2: Is there life beyond Earth's Solar System?

In this option students are introduced to ways that the question about life beyond Earth's Solar System is investigated by astronomers. Students consider the likelihood of life, including intelligent life, beyond the Solar System, the methods used to find suitably habitable planets, and how the search for life beyond the Solar System is conducted. They examine how telescopes are deployed to observe starlight from across our galaxy and to detect possible signals from other life.

Outcome 2.2

On completion of this unit the student should be able to apply concepts of light and atomic physics to describe and analyse the search for life beyond Earth's Solar System.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Information from beyond Earth's Solar System

- identify the spectrum of electromagnetic radiation as the basis for all observations of the Universe
- explain how emission and absorption line spectra are produced with reference to the transition of electrons between energy levels of the atom
- identify spectroscopy as a tool to investigate the light from stars, and interpret and analyse spectroscopic data with reference to information from beyond our Solar System
- describe how planets can be identified by using the common centre of mass and the gravitational effect of a planetary system on a star.

Locating extrasolar planets

- compare methods of exoplanet detection including astrometric, radial velocity, transit method and microlensing, referring to databases that differentiate for size, eccentricity and radius
- explain and apply Doppler shift including spectral shift and 'wobble' of planetary systems using: $\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$
- investigate how the composition of an exoplanet can be determined using spectral analysis.

Conditions for life beyond Earth's Solar System

- explain the presence of liquid water as determining the habitable zones of a star system and the most likely place for life
- explain the origins of life in the Universe as having come from organic molecules in space, or as originating on Earth or an Earth-like planet through reactions of elements and compounds.

Possibility of life beyond Earth's Solar System

- explain the use of the Fermi paradox to question the possibility of life outside Earth's Solar System and identify its counter arguments
- apply the Drake equation: $N = R^* f_p n_e f_l f_i f_c \mathrm{L}$, as a way of predicting the likelihood of life existing in the Universe by making reasonable assumptions based on evidence and speculation
- distinguish between targeted and untargeted searches for extra-terrestrial intelligence (ETI), and describe optimising strategies including where to look and how to 'listen' with reference to choice of frequency and bandwidth
- explain why the radio spectrum is the best section of the electromagnetic spectrum to search the sky for possible ETI signals, including the cosmic radio window and the use of radio astronomy in the search
- explain the nature of information that humans transmit beyond Earth to signal that intelligent life exists on Earth.

Option 2.3: How do forces act on the human body?

This option involves the application of mechanical theories and concepts to living systems with emphasis on the human body, particularly its movement, structure and function. Students observe the effects of forces acting upon a material and evaluate data relating to changes to the material. They investigate properties of structures and materials in the context of the human body and in the development and design of prosthetics.

Outcome 2.3

On completion of this unit the student should be able to analyse the physical properties of organic materials including bone, tendons and muscle, and explain the uses and effects of forces and loads on the human body.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Forces in the human body

- identify different types of external forces, including gravitational forces, that can act on a body to create compression, tension and shear
- apply centre of mass calculations to a body or system: $x_m = \frac{x_1 m_1 + x_2 m_2 + \ldots + x_n m_n}{m_1 + m_2 + \ldots + m_n}$
- investigate and apply theoretically and practically translational forces and torques $(\tau = r_{\perp} F)$ in simple lever models of human joints under load.

Materials in the human body

- calculate the stress and strain resulting from the application of compressive and tensile forces and loads to materials in organic structures including bone and muscle using: $\sigma = \frac{F}{A}$ and $\varepsilon = \frac{\Delta l}{l}$
- compare the behaviour of living tissue under load with reference to extension and compression, including Young's modulus: $E = \frac{\sigma}{\varepsilon}$
- investigate how the behaviour of living tissue under load compares with common building materials, including wood and metals
- investigate the suitability of different materials for use in the human body, including bone, tendons and muscle, by comparing tensile and compressive strength and stiffness, toughness, and flexibility under load
- calculate the potential energy stored in a material under load (strain energy) using area under stress versus strain graph
- investigate the elastic or plastic behaviour of materials under load, for example skin and membranes.

Materials used to replace body parts

- investigate the development of artificial materials and structures for use in prosthetics, including external prostheses for the replacement of lost limbs, and internal prostheses such as hip or valve replacements
- identify the difficulties and problems with implanting materials within the human body
- compare the performance of artificial limbs with natural limbs with reference to function and longevity.

Option 2.4: How can AC electricity charge a DC device?

This option investigates the processes involved in transforming the alternating current delivered by the electrical supplier into low voltage direct current for use with small current electrical devices. Students investigate a variety of circuits to explore processes including transformation, rectification, smoothing and regulation. They use a variety of instruments to observe the effects of electricity.

Outcome 2.4

On completion of this unit the student should be able to construct, test and analyse circuits that change AC voltage to a regulated DC power supply, and explain the use of transducers to transfer energy.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

240 V AC to 6 V DC

- analyse the role of the transformer in the power supply system including the analysis of voltage ratio: $\frac{N_1}{N_2} = \frac{V_1}{V_2}$ (not including induction or its internal workings)
- explain the use of diodes in half-wave and full-wave bridge rectification
- explain the effect of capacitors with reference to voltage drop and current change when charging and discharging (time constant for charging and discharging, $\tau = RC$) leading to smoothing for DC power supplies
- describe the use of voltage regulators including Zener diodes and integrated circuits
- analyse systems, including fault diagnosis, following selection and use of appropriate test equipment
- interpret a display on an oscilloscope with reference to voltage as a function of time.

Data transfer

- apply the use of heat and light sensors such as thermistors and light-dependent resistors (LDRs) to trigger an output device such as lighting or a motor
- evaluate the use of circuits for particular purposes using technical specifications related to potential difference (voltage drop), current, resistance, power, temperature and illumination
- compare different light sources (bulbs, LEDs, lasers) for their suitability for data transfer
- explain the use of optical fibres for short and long distance telecommunications.

Option 2.5: How do heavy things fly?

This option enables students to explore the aerospace principles that underpin the development of controlled powered flight and the application of these principles to aerospace design. Students observe how different forces affect flight. They investigate the principles of aerodynamics and flight control and how these principles are utilised in the design and operation of aircraft.

Outcome 2.5

On completion of this unit the student should be able to apply concepts of flight to investigate and explain the motion of objects through fluids.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Aerodynamics

- model the forces acting on an aircraft in flight as lift, drag, the force due to gravity and thrust
- identify aerodynamic forces as arising from the movement of fluid over an object
- explain the production of aerodynamic lift with reference to:
  - Bernoulli's principle and pressure differences
  - conservation of momentum and downwash
- compare contributions to aerodynamic drag, including skin friction, form and lift-induced
- explain the changes in aerodynamic behaviour at supersonic speeds, including compressibility, shock wave formation and increase in drag
- explain the production of thrust with reference to Newton's laws of motion
- investigate how it is possible for an aircraft to generate lift when flying upside down.

Manipulating flight

- calculate lift and drag forces acting on an aircraft:
  - lift: $F_L = \frac{1}{2} C_L \rho v^2 A$
  - drag: $F_D = \frac{1}{2} C_D \rho v^2 A$
- investigate theoretically and practically the variation of lift coefficient with angle of attack, including identification of stall
- model aerodynamic forces as acting at the centre of pressure and the force due to gravity as acting at the centre of mass
- calculate the torque applied by a force acting on an aircraft: $\tau = r_{\perp} F$
- describe the roles of the rudder, elevator and ailerons as the primary control surfaces on an aircraft
- apply balance of forces and torques with reference to Newton's laws of motion to:
  - controlling an aircraft in roll, pitch and yaw
  - stages of flight, including takeoff, climb, cruise, descent, landing and manoeuvres
- explain the possible advantages and difficulties in designing an unconventional aircraft, such as a flying wing.

Applications of flight

- apply aerodynamics principles beyond conventional aircraft to investigate practically and/or theoretically at least one of:
  - strategies to improve the efficiency of cars by reducing drag area $(C_D A)$
  - the design and use of aerofoil shapes to produce forces in propellers, wind turbines, racing cars or submarines
  - improving lift in boomerangs, kites or helicopters
  - the production of thrust using propellers, jet engines and rockets.

Option 2.6: How do fusion and fission compare as viable nuclear energy power sources?

Fission and fusion are nuclear reactions that produce relatively large quantities of energy from comparatively small quantities of fuel. This option enables students to compare the production of energy from fission and fusion reactions. They study a model of the atom that explains the source of the large amounts of energy produced. Students explore the viability of using nuclear power as an energy source and evaluate its benefits and risks.

Outcome 2.6

On completion of this unit the student should be able to apply the concepts of nuclear physics to describe and analyse nuclear energy as a power source.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Energy from the nucleus

- explain nuclear fusion reactions of proton-proton and deuterium-tritium with reference to:
  - reactants, products and energy production
  - availability of reactants
  - energy production compared with mass of fuel
- explain nuclear fission reactions of ^{235}U and ^{239}Pu with reference to:
  - fission initiation by slow and fast neutrons respectively
  - products of fission including typical unstable fission fragments and energy
  - radiation produced by unstable fission fragments
- describe neutron absorption in ^{238}U, including formation of ^{239}Pu
- explain fission chain reactions including:
  - the effect of mass and shape on criticality
  - neutron absorption and moderation

Nuclear energy as a power source

- compare nuclear fission and fusion with reference to:
  - energy released per nucleon and percentage of the mass that is transformed into energy
  - availability of reactants
  - limitations as a source of energy for electricity production
  - environmental impact
- analyse fission and fusion with reference to their viabilities as energy sources
- describe the energy transfers and transformations in the systems that convert nuclear energy into thermal energy for subsequent power generation
- explain the risks and benefits for society of using nuclear energy as a power source.

Option 2.7: How is radiation used to maintain human health?

In this option students use concepts of nuclear physics to explore how the use of electromagnetic radiation and particle radiation are applied in medical diagnosis and treatment. They learn about the production and simple interpretation of images of the human body produced by a variety of imaging techniques used to observe or monitor the functioning of the human body.

Outcome 2.7

On completion of this unit the student should be able to use nuclear physics concepts to describe and analyse applications of electromagnetic radiation and particle radiation in medical diagnosis and treatment.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Radiation and the human body

- distinguish between electromagnetic radiation and particle radiation
- describe how X-rays for medical use are produced including the distinction between soft and hard X-rays
- describe how medical radioisotopes may be produced by neutron bombardment and high energy collisions
- analyse decay series diagrams of medical radioisotopes with reference to type of decay and stability of isotopes
- compare ionising and non-ionising radiation with reference to how each affects living tissues and cells
- explain the effects of α, β and γ radiation on humans, including:
  - different capacities to cause cell damage
  - short- and long-term effects of low and high doses
  - ionising impacts of radioactive sources outside and inside the body
  - calculations of absorbed dose (gray), equivalent dose (sievert) and effective dose (sievert).

The use of radiation in diagnosis and treatment of human illness and disease

- compare the processes of, and images produced by, medical imaging using two or more of X-rays, computed tomography (CT), γ radiation, magnetic resonance imaging (MRI), single photon emission computed tomography (SPECT) and positron emission tomography (PET)
- describe applications of medical radioisotopes in imaging and diagnosis
- explain the use of medical radioisotopes in therapy including the effects on healthy and damaged tissues and cells
- relate the detection and penetrating properties of α, β and γ radiation to their use in different medical applications
- analyse the strengths and limitations of a selected contemporary diagnostic or therapeutic radiation technique.

Option 2.8: How do particle accelerators work?

In this option students explore the function and use of particle accelerators to produce radiation and to collide particles. The use of particle accelerators has allowed observations to be made of particles that may once have existed in nature but are no longer present. Investigation of these particles allows theories of the early Universe to be developed and challenged. Students investigate the development of, and comparisons between, various accelerator technologies. Particle accelerators and colliders include the Australian Synchrotron and the Large Hadron Collider.

Outcome 2.8

On completion of this unit the student should be able to apply the principles related to the behaviour of charged particles in the presence of electric and magnetic fields to describe and analyse the use of accelerator technologies in high energy physics.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Particle accelerators and the production of light

- distinguish between the use of particle accelerators to produce synchrotron light and to collide particles
- distinguish between the capabilities of a particle collider and the capabilities of the Australian Synchrotron
- explain the general purpose of the electron linac, circular booster, storage ring and beamlines in the Australian Synchrotron
- explain, using the characteristics of brightness, spectrum and divergence, why for some experiments synchrotron radiation is preferable to laser light and radiation from X-ray tubes.

Accelerator technology and the development of modern particle physics

- explain the evolution of collider technology including:
  - particles involved in the collision event
  - the increasing energies attained since the 1950s
- evaluate the role of colliders in the development of the Standard Model of particle physics, including reference to subatomic structure and processes
- describe the products of collisions with reference to symbol, charge, rest energy and lifespan
- compare the physical designs and purposes of particle detectors at the Large Hadron Collider including ATLAS, CMS, ALICE and LHCb.

Current and future applications of accelerator technology for society

- explain how the immense amount of data collected by the Large Hadron Collider is stored and analysed, and the associated role particle detectors have had in the development of information processing technologies
- describe at least one application of particle accelerators selected from:
  - materials analysis and modification which results in the improvement of consumer products such as heat-shrinkable film and chocolate
  - implanting of ions in silicon chips to make them more effective in electronic products such as computers and smart phones
  - nuclear energy applications such as the use of thorium as an alternative fuel for the production of nuclear energy or the treatment of nuclear waste
  - pharmaceutical research involving the analysis of protein structure leading to the development of new pharmaceuticals to treat major diseases
  - DNA research involving the analysis of protein metabolism leading to the development of new antibiotics
  - medical applications such as the production of a range of radioisotopes for medical diagnostics and treatments or cancer therapy through the use of particle beams
  - use of spectrometry in environmental monitoring or the use of blasts of electrons in the treatment of pollution such as contaminated water, sewage sludge and gases from smokestacks
  - use of particle accelerators in a selected experiment or scientific endeavour
- investigate current and proposed future directions of collider technologies.

Option 2.9: How can human vision be enhanced?

In this option students observe the behaviour of light, investigate reflection and refraction, and apply these concepts to the operation of cameras, lenses, telescopes, microscopes and the human eye.

Outcome 2.9

On completion of this unit the student should be able to apply a ray model of light and the concepts of reflection and refraction to explain the operation of optical instruments and the human eye, and describe how human vision can be enhanced.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Behaviour of light

- identify that light travels in straight lines in a uniform medium
- investigate and apply theoretically and practically the two laws of reflection at a plane surface:
  - the angle of incidence is equal to the angle of reflection
  - the incident ray, reflected ray and the normal at the point of incidence are coplanar
- investigate theoretically and practically refraction using Snell's Law, $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$.

Manipulating light for a purpose

- describe image formation using pinhole cameras and convex and concave lenses
- calculate image positions for thin lenses using either accurate ray tracing scale diagrams and/or the thin lens equation: $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
- calculate image sizes in pinhole and simple lens cameras: $M = -\frac{v}{u}$
- explain the operation of simple two-lens telescopes and microscopes.

Light and the eye

- model and explain human vision as refraction at a spherical surface with an adjusting lens
- distinguish between short-sightedness and long-sightedness, and explain their correction by concave and convex lenses, respectively
- apply the power of a lens: $P = \frac{1}{f}$ to eye glasses
- explain accommodation in the human eye including the effects of ageing
- investigate and explain the treatment of cataract blindness including the use of intraocular lenses
- investigate the operation of the bionic eye.

Option 2.10: How do instruments make music?

In this option students explore models and ideas about sound in the contexts of music and hearing. Students examine how the wave model is applied in the design and development of musical instruments including the voice. They investigate the effects of sound and consider why certain chord progressions and cadences are more appealing to the human ear than others.

Outcome 2.10

On completion of this unit the student should be able to apply a wave model to describe and analyse the production of sound in musical instruments, and explain why particular combinations of sounds are more pleasing to the human ear than others.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Concepts used to model sound

- describe sound as the transmission of energy via longitudinal pressure waves
- analyse sound using wavelength, frequency and speed of propagation of sound waves: $v = f\lambda$
- distinguish between sound intensity (W m^{-2}) and sound intensity level (dB)
- calculate sound intensity at different distances from a source using an inverse square law
- analyse a standing wave as the superposition of a travelling wave and its reflection.

Sound production

- explain resonance and identify it as related to the natural frequency of an object
- investigate factors that influence natural frequency including shape and material and explain how this relates to instruments
- investigate and explain the human voice box as a resonance chamber with vibration provided by vocal cords
- investigate and explain a variety of musical instruments with reference to the similarities and differences of sound production between instrument types (brass, string, woodwind and percussion) and how they compare with the human voice
- analyse, for strings and open and closed resonant tubes, the fundamental and subsequent harmonics and apply this analysis to selected musical instruments
- analyse the unique sound of an instrument as a consequence of multiple resonances created by the instrument and described as timbre
- investigate how the amount of diffraction around an obstacle varies with the size of the obstacle and the wavelength of the sound.

Sound detection

- describe the structure of the human ear with reference to the transfer and amplification of vibrations
- interpret the frequency response curve of the human ear
- differentiate between pitch, timbre and loudness
- identify the representation of timbre as a combination of specific frequencies
- describe how particular musical intervals can be represented as ratios of their frequencies, and how consonant frequencies tend to have simple ratios
- investigate the phenomenon of beats.
- investigate an aspect of contemporary research in psychoacoustics.

Option 2.11: How can performance in ball sports be improved?

In this option students investigate the physics of ball sports using mechanics concepts including Newton's laws of motion. Students observe and analyse motion in one and two dimensions, study associated collisions and explore the factors that maximise the projection of the ball in various sports. Students may explore ideas in a selected sport of interest or may choose a range of ball sports to investigate.

Outcome 2.11

On completion of this unit the student should be able to apply concepts of linear, rotational and fluid mechanics to explain movement in ball sports.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Motion of sports balls

- investigate and calculate theoretically and practically the transfer of momentum in elastic and inelastic collisions (limited to two dimensions) including the use of the coefficient of restitution, e
- investigate and apply theoretically and practically the coefficients of static and kinetic friction to sliding and rolling balls to calculate speeds using Newton's laws of motion and the equations of constant acceleration
- explain rolling of spherical objects using angular and linear speeds: $v = r\omega$.

Maximising flight

- model and describe qualitatively the energy transfers in the action of a double pendulum in at least one of the following:
  - the swing of a racquet, club, stick or bat
  - the throw, pitch or hurl of a ball
  - the kick of a ball
- calculate air resistance (drag) and terminal velocity: $F_D = \frac{1}{2} C_D \rho v^2 A$
- investigate and apply theoretically and practically the equations of constant acceleration to calculate the flight of objects through the air (neglecting air resistance) in two dimensions
- model and describe qualitatively the flight of:
  - a ball through the air when air resistance is not neglected
  - spinning sports balls with reference to the Magnus effect
- analyse and explain the relative influence of dynamics factors that affect the performance of equipment in ball sports.

Option 2.12: How does the human body use electricity?

In this option students focus on the production of potential difference and subsequent currents in the human body. They explore the role of electricity in nerve transmission, in sensation, and in the heart. The effects of current through the body are considered, including the operation of artificial stimulators and the use of heart defibrillators to restore heart beat. Students investigate an issue related to the production or use of electricity by the body.

Outcome 2.12

On completion of this unit the student should be able to explain the electrical behaviour of the human body and apply electricity concepts to biological contexts.

To achieve this outcome the student will draw on key knowledge outlined below and apply the key science skills on pages 11 and 12 of the study design.

Key knowledge

Electrical signals in the human body

- compare charge carriers in the human body (specifically Na^+, K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-} and Cl^- ions) with those in metals (specifically electrons)
- describe the nervous system as the control of the function of the human body through electrical processes of nerve cells (through an action potential) and chemical transfer between nerve cells (through neurotransmitters diffusing across synapses)
- describe electrical signalling in the body as occurring through electrical pulses
- model an action potential as a short lasting electrical event across the cell membrane in response to a stimulus, including reference to the roles of ion channels (leakage and voltage gated) in changing membrane potentials during the processes of depolarisation, repolarisation, hyperpolarisation and return to resting state
- explain heart beat with reference to the production of a potential difference
- model heart beat with reference to the action of the nodes in atrial and ventricular muscles as the source of the electric signal, the staggering of signals from the atrial and ventricular muscles, and time delay before both muscles can contract again.

Effects of electricity applied to the body

- describe the general principle of operation of artificial stimulators such as heart pacemakers and cochlear implants
- describe the effects of current through, and potential difference across, the human body
- relate various sensations (tingling, taste) to amplitude of current flowing through the body
- explain how a defibrillator works by storing electric charge for rapid production of large-amplitude current to restore heart rhythm.

Applications of electricity involving the human body

- apply concepts of resistance and capacitance to current and the frequency of pulses (time constant for charging and discharging, $\tau = RC$)
- apply concepts of current, resistance, potential difference (voltage drop), capacitance and power to the human body (quantitative analysis restricted to use of $I = \frac{V}{R}$ and $P = VI$)
- explain why people have different electrical resistances with reference to comparison of the resistances in human bone, fat, muscle, nerves and skin
- apply electricity concepts to describe one of:
  - use of potential difference in biomedical diagnosis with reference to electrocardiograms (ECGs) and/or electroencephalographs (EEGs)
  - the galvanic skin response and its use in polygraphs and/or biotherapy feedback devices

- neuroplasticity after spinal cord injury and use of activity-based therapies
- use of the brain, through activated muscles, to control remote devices
- cauterisation of wounds through resistive heating
- action potentials involved in detecting light by photoreceptors (three types of cones for colour; rods for detecting light and dark changes, shapes and movement).

Area of Study 3

Practical investigation

Systematic experimentation is an important aspect of physics inquiry. In this area of study students design and conduct a practical investigation related to knowledge and skills developed in Area of Study 1 and/or Area of Study 2.

The investigation requires the student to develop a question, plan a course of action that attempts to answer the question, undertake an investigation to collect the appropriate primary qualitative and/or quantitative data, organise and interpret the data, and reach a conclusion in response to the question. The student designs and undertakes an investigation involving two independent variables one of which should be a continuous variable. A practical logbook must be maintained by the student for recording, authentication and assessment purposes.

Outcome 3

On completion of this unit the student should be able to design and undertake an investigation of a physics question related to the scientific inquiry processes of data collection and analysis, and draw conclusions based on evidence from collected data.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on pages 11 and 12 of the study design.

Key knowledge

- the physics concepts specific to the investigation and their significance, including definitions of key terms, and physics representations
- the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including experiments (thermodynamics, construction of electric circuits, mechanics), and/or the evaluation of a device; precision, accuracy, reliability and validity of data; and identification of uncertainty
- identification and application of relevant health and safety guidelines
- methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of error and uncertainty, and limitations of data and methodologies
- observations and experiments that are consistent with, or challenge, current physics models or theories
- the nature of evidence that supports or refutes a hypothesis, model or theory
- the key findings of the selected investigation and their relationship to key physics concepts
- the conventions of scientific report writing including physics terminology and representations, symbols, equations and formulas, units of measurement, significant figures, standard abbreviations and acknowledgment of references.

Assessment

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study, including the key knowledge and key skills listed for the outcomes, should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessments at Units 1 and 2 are school-based. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision.

For this unit students are required to demonstrate achievement of three outcomes. As a set these outcomes encompass all areas of study in the unit.

Suitable tasks for assessment may be selected from the following:

For Outcomes 1 and 2

- an annotated folio of practical activities
- data analysis
- design, building, testing and evaluation of a device
- an explanation of the operation of a device
- a proposed solution to a scientific or technological problem
- a report of a selected physics phenomenon
- a modelling activity
- a media response
- a summary report of selected practical investigations
- a reflective learning journal/blog related to selected activities or in response to an issue
- a test comprising multiple choice and/or short answer and/or extended response.

For Outcome 3

- a report of a practical investigation (student-designed or adapted) using an appropriate format, for example a scientific poster, practical report, oral communication or digital presentation.

Where teachers allow students to choose between tasks they must ensure that the tasks they set are of comparable scope and demand.

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2. For Area of Study 3, between 7 and 10 hours of class time should be devoted to undertaking the investigation and communicating findings.