VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Physics

Victorian Certificate of Education **Study Design**

State Government Victoria

Contents

Introduction

SCOPE OF STUDY

Physics is the study of how the Universe works. By looking at the way matter and energy interact through observations, measurements and experiments, physicists gain a better understanding of the underlying laws of nature.

VCE Physics provides students with opportunities to explore questions related to the physical world. The study provides a contextual approach to exploring selected classical and contemporary areas within the discipline including astronomy, electricity, thermodynamics, mechanics, fields, waves and quantum physics. Focus studies related to astrophysics, biomechanics, electronics, flight, medical physics, nuclear energy, nuclear physics, optics, sound and sports science offer study breadth. Students engage in the creative and dynamic nature of the discipline by examining classic and contemporary research, including models and theories, that illustrate how knowledge in physics evolves in response to new evidence. An understanding of the complexities and diversity of physics leads students to appreciate the interconnectedness between different content areas both within the discipline and with other sciences.

An important feature of the VCE Physics study design is the opportunity for students to undertake a range of inquiry tasks that may be self-designed, develop skills, extend knowledge and interrogate the links between theory and practice. Inquiry methodologies may include laboratory experimentation, local and remote data logging, simulations, animations and literature reviews. Students pose questions, formulate hypotheses, collect and analyse data, evaluate methodologies and results, justify conclusions and communicate their findings to a variety of audiences. A working knowledge of the safety considerations associated with physics investigations is integral to the study of VCE Physics.

As well as an increased understanding of the scientific process, students develop capacities that enable them to evaluate critically the strengths and limitations of science, respect evidence-based conclusions and gain an awareness of the ethical, social and political contexts of scientific endeavours.

RATIONALE

Physics is a natural science based on observations, experiments, measurements and mathematical analysis with the purpose of finding quantitative explanations for phenomena occurring from the smallest scale through to the planets, solar systems and galaxies in the Universe.

Whilst many scientific understandings in Physics have stood the test of time, many other areas continue to evolve. Students develop their understanding of the role of careful and systematic experimentation, and modelling, in the development of theories and laws. They work collaboratively as well as independently on a range of tasks. Through Physics, students engage in science as a process that involves developing technologies, knowledge building, addressing societal challenges, and informing government policy. Students use scientific and cognitive skills and understandings to analyse contemporary physics-related issues, and communicate their own views from an informed position.

VCE Physics provides for continuing study pathways within the discipline and leads to a range of careers. Physicists may undertake research and development in specialist areas including acoustics, astrophysics and cosmology, atmospheric physics, computational physics, energy research, engineering, instrumentation, lasers and photonics, materials science, medical physics, nuclear science, optics and pyrotechnics. Transferable skills such as problem solving, mathematical and computer literacy, creativity and teamwork may also lead to employment in areas including business, computer science, finance, journalism, management and teaching.

AIMS

This study enables students to:

- understand and use the language and methodologies of physics
- apply physics concepts, models and theories to explain, analyse and make predictions about diverse phenomena.

Together with the other VCE science studies, VCE Physics enables students to:

- appreciate the cooperative, cumulative, evolutionary and interdisciplinary nature of science as a human endeavour, including its possibilities, limitations, and political and sociocultural influences
- develop a range of individual and collaborative science investigation skills through experimental and inquiry tasks in the field and the laboratory
- develop a critical perspective on contemporary science-based issues of local and global significance
- apply their scientific understandings to familiar and novel situations including personal, social, environmental and technological contexts
- foster attitudes that include curiosity, open-mindedness, creativity, flexibility, integrity, attention to detail and respect for evidence based conclusions
- understand and apply the research, ethical and safety principles that govern the study and practice of the discipline in the collection, analysis, and critical evaluation and reporting of data
- communicate clearly and accurately an understanding of the discipline using appropriate terminology, conventions and formats to diverse audiences.

STRUCTURE

The study is made up of four units:

Unit 1: How can the unseen be explained?

Unit 2: How do observations shape knowledge?

Unit 3: How does energy relate to nature?

Unit 4: Why are light and matter so challenging to explain?

Each unit deals with specific content contained in areas of study and is designed to enable students to achieve a set of outcomes for that unit. Each outcome is described in terms of key knowledge and is complemented by a set of key science skills.

The study is structured under a series of curriculum framing questions that reflect the inquiry nature of the discipline.

ENTRY

There are no prerequisites for entry to Units 1, 2 and 3. Students must undertake Unit 3 prior to undertaking Unit 4. Students entering Unit 3 without Units 1 and/or 2 may be required to undertake additional reading as prescribed by their teacher. Units 1 to 4 are designed to a standard equivalent to the final two years of secondary education. All VCE studies are benchmarked against comparable national and international curricula.

DURATION

Each unit involves at least 50 hours of scheduled classroom instruction over the duration of a semester.

CHANGES TO THE STUDY DESIGN

During its period of accreditation minor changes to the study will be announced in the *VCAA Bulletin*. The Bulletin is the only source of changes to regulations and accredited studies. It is the responsibility of each VCE teacher to monitor changes or advice about VCE studies published in the Bulletin.

MONITORING FOR QUALITY

As part of ongoing monitoring and quality assurance, the VCAA will periodically undertake an audit of VCE Physics to ensure the study is being taught and assessed as accredited. The details of the audit procedures and requirements are published annually in the *VCE and VCAL Administrative Handbook*. Schools will be notified if they are required to submit material to be audited.

SAFETY AND WELLBEING

It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students undertaking the study.

This study may involve the handling of potentially hazardous substances and the use of potentially hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students undertaking the study.

In Victoria, the relevant legislation for electrical safety is the *Electricity Safety Act 1998* and associated regulations. Only persons who hold an appropriate current electrical licence are permitted to carry out electrical work on products or equipment that require voltage greater than 50 volts AC or 120 volts ripple-free DC. This requirement means that students are not permitted to carry out any electrical work on electrical products or equipment that operates above 50 volts AC or 120 volts ripple-free DC.

Students are permitted to work with approved apparatus, appliances and testing equipment that operate at voltages up to 240 volts (which may include appliances such as electric drills or electric soldering irons); however, they must not access or modify any component on such apparatus or appliance.

Any product that requires voltages up to 50 volts AC or 120 volts DC in a supervised class must comply with *Wiring Rules* (AS/NZS 3000:2000) and *General requirements for electrical equipment* (AS/NZS 3100:2002).

EMPLOYABILITY SKILLS

This study offers a number of opportunities for students to develop employability skills. The *Advice for teachers* provides specific examples of how students can develop employability skills during learning activities and assessment tasks.

LEGISLATIVE COMPLIANCE

When collecting and using information, the provisions of privacy and copyright legislation, such as the Victorian *Information Privacy Act 2000* and *Health Records Act 2001*, and the federal *Privacy Act 1988* and *Copyright Act 1968,* must be met.

Assessment and reporting

SATISFACTORY COMPLETION

The award of satisfactory completion for a unit is based on the teacher's decision that the student has demonstrated achievement of the set of outcomes specified for the unit. The decision about satisfactory completion of a unit is distinct from the assessment of levels of achievement. Schools will report a result for each unit to the VCAA as S (Satisfactory) or N (Not Satisfactory).

Teachers must develop courses that provide appropriate opportunities for students to demonstrate satisfactory achievement of outcomes.

Satisfactory completion of outcomes is determined by evidence gained through assessment in a range of learning tasks and activities.

LEVELS OF ACHIEVEMENT

Units 1 and 2

Procedures for the assessment of levels of achievement in Units 1 and 2 are a matter for school decision. Assessment of levels of achievement for these units will not be reported to the VCAA. Schools may choose to report levels of achievement using grades, descriptive statements or other indicators.

Units 3 and 4

The VCAA specifies the assessment procedures for students undertaking scored assessment in Units 3 and 4. Designated assessment tasks are provided in the details for each unit in the VCE study designs.

Determination of the level of achievement is based on the student's performance in School-assessed Coursework (SACs) and/or School-assessed Tasks (SATs) as specified in the VCE study designs.

The VCAA will report students' level of performance on each assessment component as a grade from A+ to E or UG (ungraded). To receive a study score the student must achieve two or more graded assessments and receive S for both Units 3 and 4. The study score is reported on a scale of 0–50; it is a measure of how well the student performed in relation to all others who took the study. Teachers should refer to the current *VCE and VCAL Administrative Handbook* for details on graded assessment and calculation of the study score.

Percentage contributions to the study score in VCE Physics are as follows:

- Unit 3 School-assessed Coursework: 20 per cent
- Unit 4 School-assessed Coursework: 20 per cent
- End-of-year examination: 60 per cent.

Details of the assessment program are described in the sections on Units 3 and 4 in this study design.

AUTHENTICATION

Work related to the outcomes of each unit will be accepted only if the teacher can attest that, to the best of their knowledge, all unacknowledged work is the student's own. Teachers need to refer to the current *VCE and VCAL Administrative Handbook* for authentication procedures.

Units 1–4: Key science skills

A set of key science skills is essential to the study of VCE Physics and applies across Units 1 to 4 in all areas of study. In designing teaching and learning programs for each unit, teachers must ensure that students are given the opportunity to develop, use and apply these skills and to demonstrate them in a variety of contexts when undertaking their own investigations or evaluating the research of others. As the complexity of key knowledge increases from Units 1 to 4 and as multiple opportunities are provided to undertake investigations, students should demonstrate the key science skills at a progressively higher level and with greater proficiency.

For the purpose of the study design the relevant physics-specific skills, as an elaboration of the key science skills, are listed in the table below:

Key science skill	***VCE Physics Units 1–4 skills***
select questions, formulate hypotheses and make predictions	• formulate testable hypothesis, questions and predictions • identify independent, dependent and controlled variables
plan and undertake investigations	• determine appropriate type of investigation • select and use equipment, materials and procedures appropriate to the investigation
take into account safety and ethical considerations	• apply ethical principles and professional conduct as applicable when undertaking and reporting investigations • apply relevant Health and Occupational Safety Guidelines whilst undertaking practical investigations
conduct investigations to collect and record data	• systematically collect, record and summarise both qualitative and quantitative data • generate primary data, including by direct measurement, and data obtained from simulation software and data loggers • collect and use secondary data, including internet sources of data difficult to obtain in a school laboratory • use tools and techniques including the creation of simple circuits, the use of transducers to measure thermal changes or movement, the production of observable waves such as those in springs and ripple tanks • replicate procedures to obtain reliable data

Key science skill	VCE Physics Units 1–4 skills
analyse and evaluate data, methods and opinions	• use descriptive statistics including tables, bar charts, line graphs, percentages, frequency polygons, and measures of central tendency (mean, median and mode) to summarise and represent raw data • understand that conclusions derived from analysis of descriptive statistics are limited to the investigation data and cannot be generalised to a wider sample • use mathematical modelling to analyse physics concepts • evaluate investigative procedures, reliability of data and possible sources of uncertainty and bias • use a qualitative approach to analysing experimental data in terms of accuracy, precision (reproducibility), random and systematic errors, and human error, including the use of error bars on graphs
draw evidence-based conclusions	• distinguish between weak and strong evidence, and scientific and non-scientific ideas • determine whether data from an investigation supports or refutes a hypothesis or prediction being tested, or whether it leads to a new prediction or hypothesis being formulated
communicate and explain scientific ideas	• use physics language, representations, conventions, standard abbreviations, SI units of measurement and acknowledgement of sources correctly and appropriately • use clear, coherent and cogent expression

Unit 1: How can the unseen be explained?

Ideas in Physics are dynamic and as physicists explore concepts, theories evolve. Often this requires the detection, description and explanation of things that cannot be seen. In this unit students examine how Physics explains phenomena, at various scales, which are not always visible to the unaided human eye. They study large-scale phenomena through the comparison of ideas about the Universe. Medium-scale phenomena are examined by considering the effects of heat, whilst small-scale phenomena are investigated through the motion of electrons in providing electricity.

Students research key technologies, experiments and theories that led to current scientifically accepted theories of the Universe. Thermodynamic principles are used to explain phenomena related to changes in thermal energy in the contexts of cars, homes and Earth. Students apply thermal laws to investigate energy transfers within and between systems, and explore how human use of energy has had an impact on the environment. They examine the motion of electrons and explain how it can be manipulated and utilised.

AREA OF STUDY 1

Can the Universe be explained?

This area of study enables students to investigate current ideas about the Universe related to its origin, composition and possible fate. Models can be used to investigate large-scale phenomena including the shape of the Universe and the creation of dark matter. Students explore how models are used to explain observations and to make predictions, and consider the strengths and limitations of contemporary models and theories related to the Universe including the Standard Model and string theory. They explain the technologies, experiments and ideas that have led to current scientifically accepted explanations of the Universe.

Outcome 1

On completion of this unit the student should be able to analyse and discuss the evidence in support of theories about the origins, composition and future of the Universe.

To achieve this outcome the student will draw on key knowledge outlined below and the related key skills on pages 9 and 10.

Key knowledge

The origin and fate of the Universe

- outline the evidence for an increasing rate of expansion of the Universe, including red-shift as evidence of an expanding Universe, and background cosmic radiation as evidence for an expanding and cooling Universe
- explain what information is required to explore the rate of expansion of the Universe, and how the information is collected
- discuss why the Big Bang theory of Universe evolution was accepted over the Steady State theory
- compare predictions for a finite and an infinite Universe, including the impact of the shape of the Universe and dark matter.

The composition of the Universe

- outline the evidence for the strong nuclear force as a consequence of the discovery of the nucleus
- explain how particles that were initially hypothesised were later discovered experimentally, including neutrinos and the Higgs boson
- describe the Standard Model, and explain why it is challenged
- describe dark matter and dark energy, and explain why they were hypothesised
- explain why gravity is difficult to include in the Standard Model
- outline string theory as a theory that describes everything, including explanations of gravity, and describe why the theory is challenged.

Scientific exploration of the origin and composition of the Universe

- distinguish between questions, hypotheses, theories and laws
- explain how models can be used to organise and understand observed phenomena and physics concepts, and evaluate their strengths and limitations
- analyse experiments and scientific methodologies used to gain evidence in support of, or to refute, a theory about the Universe
- explain how key findings, sometimes accidentally discovered, have led to the modification or support of theories about the Universe
- describe how advances in technology have led to the development or modification of theories about the Universe
- apply scientific notation and SI units, and recognise the advantages of this notation in quantifying and comparing very large and very small quantities.

AREA OF STUDY 2

How can thermal effects be explained?

Concepts related to energy can span both large and small scales. In this area of study students investigate the thermodynamic principles related to heating processes, including concepts of temperature, energy and work. Thermal systems in Earth and human activities have environmental impacts in terms of the emission of greenhouse gases. Students explore the impacts and efficiencies of energy production in order to consider the debate about global warming and the enhanced greenhouse effect.

Students investigate principles of thermodynamics and their environmental effects through one or more of three options: the car; the home; and/or Earth.

Option 1: Thermodynamics and the car

An invention that has had a significant impact on both humans and the environment is the internal combustion engine. Thermodynamics principles may be used to explore these impacts.

- How do internal combustion engines work?
- What impact do internal combustion engines have on the environment?
- How does a four stroke internal combustion engine work?
- How does the electric motor compare with the internal combustion engine?
- Can thermodynamic principles related to the use of the internal combustion engine allow for investigation and evidence collection to inform the debate about global warming and the enhanced greenhouse effect?

Option 2: Thermodynamics and the home

The heating and cooling of homes in Australia represents a significant proportion of national energy use. Thermodynamics principles may be used to explore how increased energy efficiency may be achieved.

- Is domestic heating efficient?
- Can homes be built that don't need heating at all?

- How do the operation and efficiency of heat pumps, resistive heaters, air conditioners, evaporative coolers, solar hot water systems and electrical resistive hot water systems compare?
- How is an assessment of the energy ratings of home appliances and fittings including insulation, double glazing and window size, determined?
- Can thermodynamic principles related to the use of home appliances and fittings allow for investigation and evidence collection to inform the debate about global warming and the enhanced greenhouse effect?

Option 3: Thermodynamics and Earth

Thermal systems in Earth may be explored by the consideration of thermodynamics principles.

- How can thermodynamic principles assist in the analysis, interpretation and explanation of the changes in the thermal energy of the surface of Earth and Earth's atmosphere?
- The heat engine is a system that uses a difference in temperature to do work and ideally can be describe by four stages. Earth has two heat engines, the atmosphere and the mantle, which can be modelled using the Carnot cycle. What effect do these two cycles have on global systems?
- The maximum theoretical efficiency decreases with increasing temperatures. Does this have significant implications as global temperatures rise?
- Can thermodynamic principles related to thermal systems in Earth allow for investigation and evidence collection to inform the debate about global warming and the enhanced greenhouse effect?

Outcome 2

On completion of this unit the student should be able to apply thermodynamic principles to analyse, interpret and explain changes in thermal energy in contexts including the car, the home and/or Earth.

To achieve this outcome the student will draw on key knowledge outlined below and the related key skills on pages 9 and 10.

Key knowledge

Thermodynamics principles

- apply the First Law of Thermodynamics in simple situations
- define the Zeroth Law of Thermodynamics as two bodies in contact with each other coming to a thermal equilibrium
- convert temperature from degrees Celsius to kelvin
- define temperature as linked directly to the average kinetic energy of the atoms and molecules within a system
- calculate the kinetic energy of particles within a system using: $E_k = \frac{1}{2}mv^2$
- understand thermal energy of a monatomic gas in terms of the average kinetic energy of its particles: $U = \frac{1}{2}Nm\bar{v}^2 = \frac{3}{2}NkT$
- identify absolute zero temperature by extrapolating from a graph of volume versus temperature for an ideal gas
- describe heat transfers between and within systems as conduction, convection or radiation
- analyse the energy required to raise the temperature of a substance: $Q = mc\Delta T$
- analyse the energy required to change the state of a substance: $Q = mL$
- explain why cooling results from evaporation using a simple kinetic energy model.

Thermodynamics and global warming

- 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: $\lambda_{\max} T = \text{constant}$
- explain how some gases in the atmosphere (including methane, water and carbon dioxide) absorb and re-emit infrared radiation
- model the greenhouse effect as the flow and retention of thermal energy from the sun, Earth's surface and Earth's atmosphere.
- evaluate the influence of human activity in contributions to the enhanced greenhouse effect, including affecting surface materials and the balance of gases in the atmosphere.

AREA OF STUDY 3

How can electric circuits be understood?

Modelling is a useful tool in developing concepts that explain physical phenomena that cannot be directly observed. In this area of study, students develop circuit 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 3

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 below and the related key skills on pages 9 and 10.

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
- evaluate different analogies used to describe electric current and potential difference
- analyse electric circuits using the relationships: $I = \frac{Q}{t}$, $V = \frac{E}{Q}$, $P = \frac{E}{t} = VI$
- select, use and justify the use of 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 $R = \text{constant}$ for ohmic devices
  - equivalent effective resistance in arrangements in
    - series: $R_T = R_1 + R_2 + \ldots + R_n$ and
    - parallel: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$
- 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

- apply 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 (LDR), light-emitting diodes (LED) 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 in reference to transducers and sensors.

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)
- identify the causes, effects and treatment of electric shock in homes and recognise the approximate danger thresholds for current and duration.

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. Assessment tasks must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

Teachers should use a variety of 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 and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning and assessment activities.

As a guide, between 3½ and 5 hours of class time should be devoted to investigations in Area of Study 1 involving the use of secondary data and modelling in Area of Study 1, and to student practical work for each of Areas of Study 2 and 3.

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 three outcomes. As a set these outcomes encompass the areas of study in the unit.

Assessment tasks for this unit should be selected from the following:

- 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.

and

A selection from the following:

- annotated folio of practical activities
- data analysis
- media response
- summary report of selected practical investigations including maintenance of a logbook
- modelling activity
- reflective learning journal/blog related to selected activities or in response to an issue
- test comprising multiple-choice and/or short answer and/or extended response.

The assessment tasks may be written, oral or multi-modal.

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

Unit 2: How do observations shape knowledge?

This unit requires that students undertake a core study related to motion, one focus study of a choice of eleven focus studies, and a student-designed investigation related to motion and/or one of the eleven focus studies.

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

Students investigate the ways in which forces are involved both in moving objects and in keeping objects stationary. They choose one of eleven focus studies related to astrophysics, biomechanics, electronics, flight, medical physics, nuclear energy, nuclear physics, optics, sound, and sports science. The focus study enables students to appreciate the breadth of the discipline and to pursue an area of interest by investigating questions related to: how scientists collect information from beyond the solar system to explore stars and intelligent life other than that on Earth; how particle accelerators allow the exploration of subatomic particles and radiation; whether nuclear power is a viable energy source; how domestic power in converted to power a mobile phone; how light is manipulated to extend vision; how music is made; and how motion may be explained in the contexts of the human body, ball sports and flight.

A student-designed practical investigation related to content drawn from Area of Study 1 and/or Area of Study 2 will be undertaken in Area of Study 3.

AREA OF STUDY 1

How can motion be described?

In this unit, 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. The motion of an object can be described and analysed using specific terminology as well as graphically, numerically and algebraically.

In this area of study students will model how the mass of finite objects can be considered to be at a point called the centre of mass.

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 below and the related key skills on pages 9 and 10.

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: $F = \frac{\Delta p}{\Delta t}$
- 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 which is $9.8\ \mathrm{N\ kg^{-1}}$ 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 by A on B' or F_{AB}
- apply Newton's three laws of motion to a body on which forces act: $a = \frac{F_{\mathrm{net}}}{m}$, $F_{AB} = -F_{BA}$
- 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: $\tau = Fr_{\perp}$
- analyse 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
- analyse Hooke's Law for an ideal spring theoretically and practically: $F = -k\Delta x$
- analyse and model energy transfers and transformations using energy conservation
  - changes in gravitational potential energy near Earth's surface: $E_g = mg\Delta h$, and kinetic energy: $E_{\mathrm{k}} = \frac{1}{2}mv^2$
  - potential energy in ideal springs: $E_{\mathrm{s}} = \frac{1}{2}k\Delta x^2$, and kinetic energy: $E_{\mathrm{k}} = \frac{1}{2}mv^2$
- 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 elastic collisions between objects moving in a straight line): $I = \Delta p$.

AREA OF STUDY 2

Focus study
Eleven focus studies are available for selection in Area of Study 2. Each focus study is based on a different observation of the physical world. One focus study is to be selected from the following:

- What are stars?
- Is there intelligent life beyond Earth's solar system?
- How do forces act on the human body?
- How can AC electricity charge a DC mobile phone?
- How do heavy things fly?
- How do fusion and fission compare as viable nuclear energy power sources?
- How is radiation used in medical imaging and diagnosis?
- How do particle accelerators and colliders work?
- How can human vision be extended?
- How do instruments make music?
- How can physics be applied to improve performance in ball sports?

Focus study 2.1: What are stars?
Observations of the night sky have changed over time from just using the naked eye to the employment of sophisticated instruments. This focus study involves the examination of the birth, life and death of the stars in the Universe. Students explore how the properties of star light enables factors including its distance from Earth, temperature, composition, age and future to be determined.

Outcome 2.1
On completion of this unit the student should be able to apply the concepts of light and nuclear physics to describe, analyse and evaluate the genesis and life-cycle of stars, and the methods used to gather this information.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

Key knowledge
Astronomical measurement
- recognise how information collected about the Universe is part of the spectrum of electromagnetic radiation
- state that all electromagnetic waves travel at the same speed, c, in a vacuum
- calculate wavelength, frequency, period and speed of light: $c = f\lambda$, $T = \frac{1}{f}$
- explain production of emission and absorption line spectra in relation to electron transitions between energy levels of the atom
- identify spectroscopy as the tool for astronomers to investigate the light of stars, and interpret and analyse spectroscopic data
- apply methods (standard candles, parallax, red shift) used for measurements of the distances to stars and galaxies 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 the use of these properties in the classification of stars
- explain fusion as the energy source of a star including: $E = mc^2$
- explain nuclear fusion phenomena as they 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
- explain the formation of galaxies, stars 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 determine the Schwarzchild radius
- describe the effects of gravitational fields on space and time
- compare the Milky Way galaxy to other galaxies with different shape, colour or size
- explain and analyse how chemical composition of stars and galaxies is used to determine their age
- interpret and apply appropriate data from relevant databases to investigate aspects of stellar life cycles.

Focus study 2.2: Is there intelligent life beyond Earth's solar system?

Life beyond the solar system has intrigued many people over time. In this study, students are introduced to ways that the question about intelligent life beyond Earth's solar system is investigated by astronomers. Students consider the likelihood of intelligent life beyond Earth's solar system, the methods used to find suitably habitable planets, and how the search for intelligent life is conducted. They examine how telescopes are deployed to observe star light from across our galaxy and to detect possible signals from other intelligent life.

Outcome 2.2

On completion of this unit the student should be able to apply concepts of light and atomic physics to describe, analyse and evaluate the search for intelligent life in the galaxy.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

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 in relation to transition of electrons between energy levels of the atom
- interpret and apply spectroscopy as the tool used by astronomers to investigate the light of stars
- describe how the common centre of mass and the gravitational effect of a planetary system on a star can be used to identify planets.

Locating extrasolar planets

- evaluate methods of detection of exoplanets including astrometric, radial velocity, transit method and microlensing and use data bases for size, eccentricity and radius
- explain Doppler shift including spectral shift and 'wobble' of planetary systems: $\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$
- investigate how the composition of an exoplanet can be determined.

Life beyond Earth's solar system

- identify the habitable zones of a star system as the likely place for life, based on the presence of liquid water
- describe that the origins of life in the Universe may have come from organic molecules in space, originated on Earth or an Earth-like planet through the combinations of chemicals as shown by the Miller-Urey experiment, and which may also have emerged on Mars.

Locating intelligent life beyond Earth's solar system

- explain the use of the Fermi paradox to question the possibility of intelligent life outside the solar system and consider its counterarguments
- apply the Drake equation: $N = R_* f_p n_e f_l f_i f_c L$, 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 outline optimising strategies including where to look and how to 'listen' in terms of 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
- investigate the contribution of domestic Internet-connected computers in the search for ETI
- identify the nature of information that humans transmit beyond Earth as evidence that intelligent life exists on Earth.

Focus study 2.3: How do forces act on the human body?

This study applies 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 and explain the physical properties of organic materials including bone, tendons and muscle, and evaluate the uses and effects of forces and loads on the human body.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

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: $x_m = \dfrac{x_1 m_1 + x_2 m_2 + \ldots + x_n m_n}{m_1 + m_2 + \ldots + m_n}$
- investigate and apply translational forces and torques ($\tau = F r_\perp$) in simple lever models of human joints under load.

Materials in the human body

- compare the behaviour of living tissue under load in terms of extension and compression, including Young's modulus: $E = \dfrac{\sigma}{\varepsilon}$
- investigate how the behaviour of living tissue under load compares with common building materials, for example, wood and steel
- 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: $\sigma = \dfrac{F}{A}$ and $\varepsilon = \dfrac{\Delta l}{l}$
- evaluate 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 use and 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 in terms of function and longevity.

Focus study 2.4: How can AC electricity charge a DC mobile phone?

This detailed study 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 which 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 the following key knowledge and apply the key skills listed on pages 9 and 10.

Key knowledge

240 V AC to 5 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 in terms of 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
- evaluate the effects of test equipment on the system used to analyse and fault find
- interpret a display on an oscilloscope in terms of 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 lights 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
- discuss the use of optical fibres for short and long distance telecommunications.

Focus study 2.5: How do heavy things fly?

This focus study explores the aerospace principles that underpin the development of controlled powered flight, and their application to aerospace design. Students observe and explain how different forces affect flight. They investigate the principles of aerodynamics and flight control, and explain 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 the concepts of flight to explain, analyse and investigate the motion of objects through fluids.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

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 in terms of:
  - Bernoulli's principle and pressure differences
  - conservation of momentum and downwash
- compare contributions to aerodynamic drag, including skin friction, form and lift-induced
- describe the changes in aerodynamic behaviour at supersonic speeds including compressibility, shock wave formation and increase in drag
- explain the production of thrust in terms of Newton's Laws
- 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 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: $\tau = F r_\perp$
- identify the primary control surfaces on an aircraft as the rudder, elevator and ailerons
- apply balance of forces and torques in terms of Newton's Laws to:
  - controlling an aircraft in roll, pitch and yaw
  - stages of flight, including takeoff, climb, cruise, descent, landing and manoeuvres
- evaluate the possible advantages and difficulties in designing an unconventional aircraft, such as a flying wing.

Applications of flight
- investigate applications of aerodynamics beyond conventional aircraft (boomerangs, kites, wind turbines, rockets, helicopters, cars, ships or submarines), for example:
  - strategies to improve the efficiency of cars by reducing drag and area ($C_D A$)
  - the use of aerofoil shapes to produce forces in propellers, wind turbines, racing cars, and submarines
  - the production of thrust using propellers, jet engines and rockets.

Focus study 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 focus study 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 the nuclear power as an energy source, and evaluate the benefits and risks of using nuclear power.

Outcome 2.6
On completion of this unit the student should be able to apply the concepts of nuclear physics to describe, analyse and evaluate nuclear energy as a power source

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

Key knowledge
Energy from the nucleus
- explain nuclear stability in terms of the strong nuclear force that operates over very small distances
- explain nuclear energy as energy resulting from the conversion of mass: $E = mc^2$
- explain nuclear fusion reactions of proton-proton and deuterium-tritium in terms of
  - 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 in terms of
  - 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
  - effect of mass and shape on criticality
  - neutron absorption and moderation
- explain, using a binding energy curve, why both fusion and fission are reactions that produce energy.

Nuclear energy as a power source
- compare nuclear fission and fusion in terms of
  - energy released per nucleon and percentage of the mass that is transformed into energy
  - availability of reactants
  - limitations in terms of producing energy for electricity production
  - environmental impact
- discuss and compare fission and fusion in terms of 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
- discuss the risks and benefits for society of using nuclear energy as a power source.

Focus study 2.7: How is radiation used in medical imaging and diagnosis?
In this study, students use concepts of nuclear physics to explore how the use of radioisotopes and radiation from the nucleus are applied in medical diagnosis and treatment. They describe the production and simple interpretation of images of the human body produced by a variety of imaging techniques to observe the functioning of the human body. Radiation has many applications in medical diagnosis and treatment.

Outcome 2.7
On completion of this unit the student should be able to apply concepts of nuclear physics to describe, analyse and evaluate the applications of medical diagnosis and imaging.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

Key knowledge

Nuclear decay of medical isotopes

- describe the radioactive decay of unstable nuclei in terms of half-life
- identify decay as random with a particular half-life, including mathematical modelling in terms of whole half-lives
- analyse the origin of α, β and γ radiation, including changes to the number of nucleons
- apply the detection and penetrating properties of α, β and γ radiation for their use for different purposes
- interpret nuclear transformations using decay equations involving α, β and γ radiation
- analyse decay series diagrams of medical radioisotopes in terms of type of decay and stability of isotopes
- investigate other sources of radiation used in medicine, including x-rays and positrons.

Radiation and the human body

- define ionising radiation and recognise its effect on human tissue
- analyse the effects of α, β and γ radiation on humans including:
  - describing the short- and long-term effects of low and high doses
  - assessing the implications of external and internal sources
  - performing calculations of absorbed dose (gray), equivalent dose (sievert) and effective dose (sievert).

The use of radiation in medicine

- identify the applications of radioisotopes to medical imaging and diagnosis
- 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) and positron emission tomography (PET)
- explain the use of medical isotopes in therapy including the effects on healthy as well as infected cells
- describe the production of medical radioisotopes by neutron bombardment and high energy collisions
- discuss sources of bias and error in written and other media related to nuclear physics.

Focus study 2.8: How do particle accelerators and colliders work?

In this focus study students explore the acceleration of particles and the subsequent production of electromagnetic radiation in particle accelerators and colliders. The use of particle accelerators has allowed observations to be made of particles that may no longer exist in nature. Investigation of these particles allows theories of the early Universe to be 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 evaluate the use of accelerator technologies in high energy physics.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

Key knowledge

Particle accelerators and colliders

- describe light as an electromagnetic wave which is produced by the oscillation of charges which in turn produces changing electric fields and associated changing magnetic fields
- describe the production of synchrotron radiation by an electron radiating energy at a tangent to its circular path
- explain the general purpose of the electron linac, circular booster, storage ring and beamlines in The Australian Synchrotron
- compare the capabilities of a particle collider with The Australian Synchrotron.

Accelerator technology and the development of modern particle physics

- explain the evolution of collider technology including:
  - particles involved in the collision event
  - the increasing energy levels attained since the 1950s
- evaluate the role of colliders in the development of the Standard Model of particle physics, including understanding of sub-atomic structure and processes
- compare the physical designs of particle detectors at the Large Hadron Collider including ATLAS, CMS and LHCb.

Other applications of accelerator technology and future developments

- 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
- 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
- suggest possible future directions of collider technologies.

Focus study 2.9: How can human vision be extended?

In this study, students observe the behaviour of light, investigate reflection and refraction, and apply these concepts to the operation of optical instruments and the eye. Humans and most animals depend on light and the capacity to observe the world around them for survival.

Outcome 2.9

On completion of this unit the student should be able to apply a ray model of light and concepts of reflection and refraction to explain human and animal vision and its enhancement.

To achieve this outcome students will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

Key knowledge

Behaviour of light

- identify that light travels in straight lines in a uniform medium
- apply 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 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

- explain human vision (modelled as refraction at a spherical surface with an adjusting lens)
- describe 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 the treatment of cataract blindness including intraocular lenses
- investigate the operation of the bionic eye.

Focus study 2.10: How do instruments make music?

In this focus study, students investigate models and ideas about sound in the contexts of music and hearing.

Music can be explained in terms of the behaviour of waves. Students explore how the wave model is applied in the design and development of musical instruments (including the voice). They observe the effects of sound and understand 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, analyse and evaluate 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 the following key knowledge and apply the key skills listed on pages 9 and 10.

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: $v = f\lambda$
- analyse the differences between sound intensity ($\mathrm{W\ m^{-2}}$) and sound intensity level (dB)
- calculate sound intensity at different distances from a source using an inverse square law, excluding acoustic power
- analyse a standing wave as the superposition of a travelling wave and its reflection.

Sound production

- describe resonance and identify it as related to the natural frequency of an object
- investigate the factors that influence the natural frequency such as shape and material and 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 (brass, string, woodwind, keyboard and percussion) in terms of the similarities and differences of sound production between instrument types and how they compare to the human voice
- analyse, for strings and open and closed resonant tubes, the fundamental and subsequent harmonics and apply this understanding to particular musical instruments
- analyse the unique sound of an instrument as a consequence of multiple resonances created by the instrument and described as timbre
- describe diffraction as the directional spread of various frequencies.

Sound detection

- evaluate the structure of the human ear in relation to the transfer and amplification of vibrations
- interpret the frequency response curve of the human ear
- describe the difference between pitch and tone
- identify the representation of timbre by specific frequencies
- describe how particular musical intervals can be represented as ratios of their frequencies, and how consonant frequencies tend to have simple ratios
- examine the phenomenon of beats
- identify psychoacoustics as the scientific study of sound perception.

Focus study 2.11 How can physics be applied to improve performance in ball sports?

In this focus study, students investigate the physics of ball sports using the physics of motion, including Newton's Laws. Students observe motion in one or 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 aspects of linear, rotational and fluid mechanics to explain how performance in ball sports may be improved.

To achieve this outcome students will draw on the following key knowledge and apply the key skills listed on pages 9 and 10.

Key knowledge

Motion of sports balls

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

Maximising flight

- describe qualitatively the energy transfers in the action of a double pendulum, for example, the swing of a golf club, the throwing action of the arm, the kicking of balls, or in swinging a squash racquet
- calculate air resistance (drag) and terminal velocity/speed: $F_D = \frac{1}{2} C_D \rho v^2 A$
- apply the equations of constant acceleration to calculate the flight of objects through the air (neglecting air resistance)
- describe qualitatively the flight of a ball through the air when air resistance is not neglected
- describe qualitatively the flight of spinning sports balls using the Magnus effect.

AREA OF STUDY 3

Student-designed practical investigation

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

The investigation requires the student to ask 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. A practical logbook should be maintained by the student for recording, authentication and assessment purposes.

Outcome 3

On completion of this unit, students will be able to design and undertake an investigation of a physics question that demonstrates the scientific inquiry processes of collecting and analysing relevant data, and reach an evidence-based conclusion in response to their question.

To achieve this outcome the student will draw on knowledge outlined below and the related key science skills on pages 9 and 10 of the study design.

Key knowledge

- concepts specific to the investigation and explanation of their significance, including definitions of key terms, and physics representations
- characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including consideration of repeatability, reproducibility, reliability and validity of data, and identification of systematic error
- identification and application of relevant health and safety guidelines
- methods of organising, analysing and evaluating primary data: relevant descriptive statistics and their limitations; sources of uncertainty; limitations of data and methodologies
- use of models in organising and understanding observed phenomena and physics concepts, and their limitations
- key findings of the selected investigation and their relationship to key physics concepts
- nature of evidence that supports or refutes a hypothesis
- conventions of scientific report writing and scientific poster presentation, including correct physics language, symbols, equations, SI units of measurement, significant figures, representations, standard abbreviations, and correct acknowledgement 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. Assessment tasks must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

Teachers should use a variety of 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 and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning and assessment activities.

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 for each of Areas of Study 1 and 2. An investigation related to content drawn from Area of Study 1 and/or Area of Study 2 will be undertaken in Area of Study 3. Between 7 and 10 hours of class time should be devoted to undertaking the investigation.

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 three outcomes. As a set these outcomes encompass the areas of study in the unit.

Assessment tasks for this unit should be selected from the following:

For Outcomes 1 and 2:

A selection from the following:

- annotated folio of practical activities
- data analysis
- media response
- summary report of selected practical investigations including maintenance of a logbook
- modelling activity

- reflective learning journal/blog related to selected activities or in response to an issue
- test comprising multiple choice and/or short answer and/or extended response.

The assessment tasks may be written, oral or multi-modal.

and

For Outcome 3:

- 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.

Unit 3: How does energy relate to nature?

Theories and models related to energy attempt to conceptualise and explain the nature of the physical world. This in turn enables the development of innovative products and technologies for society. For example, concepts related to magnetic and electric fields have enabled the transmission of electricity over large distances whilst the design and construction of digital cameras and particle accelerators and colliders has relied on the application of field concepts. Relativistic theories have been integral to the development of the Global Positioning System.

In this unit, students explore the importance of energy in explaining and describing nature. They examine the production of electricity and its delivery to homes. Students consider the field model as a construct that has enabled an understanding of why objects move when they are not apparently in contact with other objects. They explore the interactions, effects and applications of gravitational, electric and magnetic fields. Students use Newtonian theories to investigate motion in one and two dimensions, and are introduced to Einsteinian theories to explain the motion of very fast objects.

Students learn that developing technologies that probe beyond what has previously been possible can challenge existing explanations of the physical world, requiring a review of conceptual models and theories.

A student-designed practical investigation related to waves, fields or motion is to be undertaken either in Unit 3, in Unit 4, or across both Unit 3 and Unit 4, and will be assessed in Unit 4 as Outcome 3.

AREA OF STUDY 1

How do things move when there is no contact?

In this area of study, students examine the similarities and differences between three fields: gravitational, electrical and magnetic. Field models are used to explain the motion of objects when there is no apparent contact. Students learn that positions in fields determine the potential energy of an object and the force on an object. They investigate how concepts related to field models can be applied to make motors and to accelerate particles through contexts including digital cameras, The Australian Synchrotron and the Large Hadron Collider.

Outcome 1

On completion of this unit the student should be able to analyse gravitational, electrical and magnetic fields, and use these to explain the operation of motors and particle accelerators.

To achieve this outcome the student will draw on key knowledge outlined below and the related key skills on pages 9 and 10.

Key knowledge

Fields and interactions

- describe gravitation, magnetism and electricity using a field model
- compare gravitation, magnetic and electric fields including directions and shapes of fields, attractive and repulsive fields, dipoles and monopoles.
- compare gravitational fields and electric fields about a point mass or charge (positive or negative) in terms of
  - the direction of the field
  - the shape of the field
  - the use of the inverse square law to determine the magnitude of the field
  - qualitatively, potential energy changes associated with a point mass or charge moving in the field
- apply a vector field model to magnetic phenomena including shapes and directions of fields produced by bar magnets, and by current-carrying wires, coils and solenoids
- identify fields as static or changing, and uniform or non-uniform.

Effects of fields

- analyse the use of a uniform electric field to accelerate a charged particle including
  - electric field and electric force concepts using: $E = k\frac{Q}{r^2}$ and $F = k\frac{q_1 q_2}{r^2}$
  - potential energy changes in a uniform field: $W = qV$, $E = \frac{V}{d}$
  - the magnitude of the force on a charged particle: $F = qE$
- analyse the use of a magnetic field to change the path of a charged particle including
  - the magnitude and direction of the force applied to an electron beam by a magnetic field: $F = qvB$ in cases where the directions of v and B are perpendicular or parallel
  - the radius of the path followed by a low-velocity electron in a magnetic field: $qvB = \frac{mv^2}{r}$
- analyse the use of gravitational fields to accelerate mass including
  - gravitational field and gravitational force concepts using: $g = G\frac{M}{r^2}$ and $F_g = G\frac{m_1 m_2}{r^2}$
  - potential energy changes in a uniform field: $E_g = mg\Delta h$
  - gravitational potential energy from area under force-distance graph and area under field-distance graph multiplied by mass

Application of field concepts

- apply the concepts of force due to gravity, F_g, and normal reaction force, F_N, including satellites in orbit where the orbits are assumed to be uniform and circular
- model satellite motion (artificial, moon, planet) as uniform circular orbital motion: $a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
- describe the interaction of two fields, allowing that electric charges, magnetic poles and current carrying conductors can either attract or repel, whereas masses only attract each other
- analyse the force on a current carrying conductor due to an external magnetic field, $F = nIlB$ where the directions of I and B are either perpendicular or parallel to each other

- analyse the operation of simple DC motors consisting of one coil, containing a number of loops of wire, which is free to rotate about an axis in a uniform magnetic field and including the use of a split ring commutator
- apply field concepts to mass spectrometers and accelerators including The Australian Synchrotron and the Large Hadron Colllider.

AREA OF STUDY 2

How efficient is the delivery of electrical energy to homes?

The production and use of electricity has had a major impact not only on human lifestyles but also on the environment.

In this study, students use evidence and models of electrical, magnetic and electromagnetic effects to explain how electricity is produced and delivered to homes. They calculate efficiencies involved in this method of energy distribution and consider its impact on both human quality of life and the environment.

Outcome 2

On completion of this unit the student should be able to analyse and evaluate an electricity generation and distribution system.

To achieve this outcome the student will draw on key knowledge outlined below and the related key skills on pages 9 and 10.

Key knowledge

Generation of electricity

- calculate magnetic flux when the magnetic field is perpendicular to the area, and describe the qualitative effect of differing angles between the area and the field: $\Phi_B = B_{\perp}A$
- analyse the generation of electromotive force (emf) including AC voltage and calculations using induced emf: $\mathcal{E} = -N\frac{\Delta\Phi_B}{\Delta t}$, in terms of:
  - rate of change of magnetic flux
  - number of loops through which the flux passes
  - direction of induced emf in a coil
- explain the production of DC voltage in DC generators and AC voltage in alternators, including the use of split ring commutators and slip rings respectively.

Transmission of electricity

- compare sinusoidal AC voltages produced as a result of the uniform rotation of a loop in a constant magnetic field in terms of frequency, period, amplitude, peak-to-peak voltage (V_{p-p}) and peak-to-peak current (I_{p-p})
- compare alternating voltage expressed as the root-mean-square (rms) to a constant DC voltage developing the same power in a resistive component
- convert between rms, peak and peak-to-peak values of voltage and current
- analyse transformer action in terms of electromagnetic induction for an ideal transformer: $\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$
- analyse supply of power by considering transmission losses across transmission lines
- evaluate the use of transformers (assumed ideal) in an electricity distribution system.

Impact of electricity

- analyse the impact of generation and distribution of electricity on quality of human life and the environment
- justify the use of AC power as a domestic power supply.

AREA OF STUDY 3

Is there a limit to how fast things can go?

In this study, students use Newtonian models to analyse relative motion, circular motion and projectile motion. Newtonian theories give important insights into a range of motion both on Earth and beyond. At very high speeds, however, Newtonian theories are insufficient to model motion and Einsteinian theories provide a better model. Students compare Newtonian and Einsteinian explanations of motion and evaluate the circumstances in which they can be applied. They explore the relationships between force, energy and mass, and explain how relativity is used in everyday contexts including the Global Positioning System (GPS).

Outcome 3

On completion of this unit the student should be able to investigate motion and related energy transformations experimentally, analyse motion using the Newtonian model in one and two dimensions, and describe the motion of objects moving at very large speeds using Einsteinian models.

To achieve this outcome the student will draw on key knowledge outlined below and the related key skills on pages 9 and 10.

Key knowledge

Newtonian theories of motion

- calculate relative velocity in one and two dimensions
- apply Newton's three laws of motion in situations where two or more coplanar forces act along a straight line and in two dimensions
- analyse the uniform circular motion of an object moving in a horizontal plane ($F_{\text{net}} = \frac{mv^2}{r}$) examples include a vehicle moving around a circular road, a vehicle moving around a banked track, or an object on the end of a string
- apply Newton's second law to circular motion in a vertical plane (forces at the highest and lowest positions only)
- analyse the motion of projectiles near Earth's surface, including a qualitative description of the effects of air resistance
- apply the laws of energy and momentum conservation in isolated systems.

Einsteinian theories of motion

- describe Einstein's two postulates for his special theory of relativity and compare them to classical physics:
  - the laws of physics are the same in all inertial (non-accelerated) frames of reference
  - the speed of light has a constant value for all observers regardless of their motion or the motion of the source
- describe the concepts of proper time (t_0), time interval between two events in a reference frame where the two events occur at the same point in space.
- describe proper length (L_0) as the quantity that is measured in the frame of reference in which objects are at rest
- model mathematically time dilation and length contraction at speeds approaching c using the equations: $t = t_0\gamma$ and $L = \frac{L_0}{\gamma}$ where $\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$

Relationships between force, energy and mass

- analyse impulse in an isolated system for collisions between objects moving in a straight line: $F\Delta t = m\Delta v$
- apply the concept of work done by a constant force using
  - work done = constant force × distance moved in direction of net force
  - work done = area under force-distance graph

- analyse transformations of energy between: kinetic energy; strain potential energy; gravitational potential energy; and energy dissipated to the environment considered as a combination of heat, sound and deformation of material
  - kinetic energy at low speeds: $E_\text{k} = \frac{1}{2}mv^2$; elastic and inelastic collisions in terms of conservation of kinetic energy
  - strain potential energy, that is, area under force-distance graph including ideal springs obeying Hooke's Law: $E_\text{s} = \frac{1}{2}k\Delta x^2$
- interpret Einstein's prediction by showing that the total 'mass-energy' of an object is given by: $E_\text{tot} = E_\text{k} + E_0 = \gamma mc^2$ where $E_0 = mc^2$, and so kinetic energy, $E_\text{k} = (\gamma - 1)mc^2$.

Relativity

- describe how matter is converted to energy by nuclear fusion in the Sun, which leads to its mass decreasing and the emission of electromagnetic radiation
- explain why muons can reach Earth even though their half-lives would suggest that they should decay in the outer atmosphere
- explain the reliance of the Global Positioning System (GPS) on relativistic calculations of time to ensure precise calculations of position.

SCHOOL-BASED ASSESSMENT

Satisfactory completion

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 assessment tasks to provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning and assessment activities.

Practical work and assessment

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 for each of Areas of Study 1 and 2. A practical investigation related to waves, fields or motion is to be undertaken either in Unit 3, in Unit 4, or across both Unit 3 and Unit 4, and will be assessed in Unit 4 as Outcome 3. The outcomes of the investigation will be presented in a scientific poster format. Between 7 and 10 hours of class time should be devoted to the investigation, including writing of the sections of the scientific poster.

Assessment of levels of achievement

The student's level of achievement in Unit 3 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be a part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. The VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and the assessment of student work for a level of achievement

Teachers will provide to the VCAA a numerical score representing an assessment of the student's level of achievement.

The score must be based on the teacher's assessment of the performance of each student on the tasks set out in the following table.

Contribution to final assessment

School-assessed Coursework for Unit 3 will contribute 20 per cent to the study score.

Outcomes	Marks allocated*	Assessment tasks
Outcome 1 Analyse gravitational, electrical and magnetic fields, and use these to explain the operation of motors and particle accelerators	30	For Outcomes 1, 2 and 3: At least one different task for each Outcome selected from: • annotations of at least two practical activities from a practical logbook • report of a student investigation • analysis of data including generalisations and conclusions • media analysis/response • extended response questions • reflective blog • test (short answer and extended response) (approximately 50 minutes per task)
Outcome 2 Analyse and evaluate an electricity generation and distribution system.	30	
Outcome 3 Investigate motion and related energy transformations experimentally, analyse motion using the Newtonian model in one and two dimensions, and describe the motion of objects moving at very large speeds using Einsteinian models.	30	
Total marks	**90**	

*School-assessed Coursework for Unit 3 contributes 20 per cent.

Unit 4: Why are light and matter so challenging to explain?

Scientific endeavour has resulted not only in practical inventions including polarised lenses and liquid crystal displays, but also in theories and models that provide explanations for physical phenomena. A complex interplay exists between theory and experiment in generating models for some of our trickiest natural phenomena including light and electromagnetic radiation in general. Wave theory has classically been used to explain phenomena related to light, but continued probing of both light and matter has revealed the particle-like properties of light. On very small scales, light and matter – which initially seem to be quite different – have been observed as having similar properties.

In this unit, students explore the concept of the wave and how it is used to explain the nature of light. They apply and analyse the limitations of the use of wave concepts in explaining the behaviour of light. Students build their understanding of light by using a particle model to explain its behaviour. They use the wave model to explain the behaviour of matter and consider the relationship between light and matter. Students are challenged to think beyond the concepts experienced in everyday life to consider the physical world from a new perspective.

A student-designed practical investigation related to waves, fields or motion is to be undertaken either in Unit 3, in Unit 4, or across both Unit 3 and Unit 4, and will be assessed in Unit 4 as Outcome 3.

AREA OF STUDY 1

How can waves explain the behaviour of light?

In this area of study, students use experimental evidence to explore wave concepts in a variety of applications. Wave theory has been used to describe transfers of energy, and is important in explaining phenomena including reflection, refraction, interference and polarisation. Do waves need a medium in order to propagate and, if so, what is the medium? Students investigate the properties of mechanical waves, and evaluate electromagnetic radiation in the context of whether light is a wave. They apply quantitative models to explore how light changes direction, including reflection, refraction, colour dispersion and polarisation.

Outcome 1

On completion of this unit the student should be able to apply wave principles to analyse, interpret and explain wave phenomena.

To achieve this outcome the student will draw on key knowledge outlined below and the related key skills on pages 9 and 10.

Key knowledge

Properties of mechanical waves

- describe a mechanical wave as a disturbance that travels through a medium
- explain a wave as the transmission of energy through a medium, without the net transfer of matter
- identify transverse and longitudinal waves
- identify the amplitude, wavelength, period and frequency of waves
- calculate the wavelength, frequency, period and speed of travel of waves using: $v = f\lambda = \frac{\lambda}{T}$
- analyse constructive and destructive interference from two sources in terms of coherent waves and path difference: $n\lambda$ and $\left(n - \frac{1}{2}\right)\lambda$
- explain resonance as the superposition of a travelling wave and its reflection, and in terms of a forced oscillation matching the natural frequency of vibration
- explain diffraction as the directional spread of various frequencies in terms of different gap width or obstacle size, including the qualitative effect of changing the $\frac{\lambda}{w}$ ratio.

Light as a wave

- describe light as an electromagnetic wave which is produced by the oscillation of charges, which in turn produces changing electric fields and associated changing magnetic fields
- state that all electromagnetic waves travel at the same speed, c, in a vacuum
- compare the wavelength and frequencies of different regions of the electromagnetic spectrum including radio, microwave, infrared, visible, ultraviolet, x-ray and gamma, and recognise that each has distinct uses in society.

Changing direction

- analyse and investigate the behaviour of waves including
  - reflection: $\theta_i = \theta_r$
  - refraction using Snell's Law: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$ and $n_1 v_1 = n_2 v_2$
  - total internal reflection and critical angle including applications: $n_1 \sin(\theta_C) = n_2 \sin(90°)$
- explain colour dispersion in prisms and lenses in terms of refraction of the components of white light as they pass from one medium to another
- describe the colour components of white light as different frequencies of light.

Polarisation of light

- describe polarised and non-polarised light
- describe polarisation by reflection and refraction of light
- evaluate Brewster's Angle: $\tan(\theta_B) = \frac{n_2}{n_1}$
- investigate and analyse the intensity of transmitted light using one polariser and two polarisers with differing angles between polarising planes
- describe the use of polarisation in sunglasses, structural stress diagnosis, determination of concentrations of solutions and in liquid-crystal displays (LCDs).

AREA OF STUDY 2

How are light and matter similar?

In this area of study, students explore how human ingenuity in the design of major experiments has led to the development of theories to describe the most fundamental aspects of the physical world – light and matter. Students are introduced to Heisenberg's uncertainty principle and the idea that it is physically impossible to simultaneously know both position and momentum with certainty.

When light and matter are probed they appear to have remarkable similarities. Light, which was previously described as an electromagnetic wave, appears to exhibit both wave-like and particle-like properties. Historically, this led to a more detailed investigation of matter which was once modelled as made up of particles: findings that electrons behave in a wave-like manner challenged thinking about the relationship between light and matter.

Outcome 2

On completion of this unit the student should be able to provide evidence for the nature of light and matter, and analyse the data from experiments that supports this evidence.

To achieve this outcome the student will draw on key knowledge outlined below and the related key skills on pages 9 and 10.

Key knowledge

Behaviour of light

- explain the results of Young's double slit experiment in terms of:
  - evidence for the wave-like nature of light
  - constructive and destructive interference of coherent waves in terms of path differences: $n\lambda$ and $\left(n-\frac{1}{2}\right)\lambda$ respectively
  - effect of wavelength, distance of screen and slit separation on interference patterns: $\Delta x = \frac{\lambda L}{d}$
- describe the effects of varying the width of a gap or diameter of an obstacle on the diffraction pattern produced by light and apply this to limitations of imaging using light
- analyse the photoelectric effect in terms of:
  - evidence for the particle-like nature of light
  - experimental data in the form of graphs of photocurrent versus electrode potential, and of kinetic energy of electrons versus frequency
  - kinetic energy of emitted photoelectrons: $E_{\mathrm{k\,max}} = hf - \phi$, using energy units of joule and electron-volt
  - effects of intensity of incident irradiation on the emission of photoelectrons
- describe the limitation of the wave model of light in explaining the photoelectric effect experimental results.

Matter as particles or waves

- interpret electron diffraction patterns as evidence for the wave-like nature of matter
- compare the diffraction patterns produced by photons and electrons
- calculate the de Broglie wavelength of matter: $\lambda = \frac{h}{p}$.

Similarities between light and matter

- compare the momentum of photons and of matter of the same wavelength including calculations using: $p = \frac{h}{\lambda}$
- explain the production of atomic absorption and emission line spectra, including those from metal vapour lamps
- interpret spectra and calculate the energy of absorbed or emitted photons: $\Delta E = hf$
- analyse the absorption of photons by atoms, in terms of:
  - the change in energy levels of the atom due to electrons changing state
  - the frequency and wavelength of emitted photons: $E = hf = \frac{hc}{\lambda}$
- describe the quantised states of the atom in terms of electrons forming standing waves, and recognise this as evidence of the dual nature of matter
- describe atomic energy levels in terms of Schrödinger and De Broglie's 'electron in a box' model which models the electron as a standing wave
- interpret the standing wave amplitude as being related to the probability of locating the electron at that position for a particular time
- interpret the single photon/electron double slit experiment as evidence in support of the dual nature of light/matter
- describe Heisenberg's uncertainty principle which shows that the position and momentum of a particle cannot both be measured with certainty simultaneously
- explain how the double slit experiment can be used to illustrate the uncertainty principle.

AREA OF STUDY 3

Student-designed practical investigation

A student-designed practical investigation related to waves, fields or motion is to be undertaken in either Unit 3, Unit 4 or across Units 3 and 4. The investigation should relate to ideas and skills developed across Units 3 and 4 and should be investigated directly by the student though practical work.

The investigation requires the student to ask a question, formulate a hypothesis, plan a course of action that attempts to answer the question and that takes into account safety and ethical considerations, undertake an experiment which involves the collection of primary quantitative data, analyse and evaluate the data, identify limitations of data and methods, link experimental results to science ideas, reach a conclusion in response to the question and suggest further investigations which may be undertaken. Results should be communicated in a scientific poster format according to a template which is included below and elaborated in the *Advice for teachers*. A practical logbook should be maintained by the student for record, authentication and assessment purposes.

Outcome 3

On completion of this unit the student should be able to design and undertake an investigation related to waves, fields or motion, and present methodologies, findings and conclusions as a scientific poster.

To achieve this outcome the student will draw on key knowledge outlined below and the related key science skills on pages 9 and 10.

Key knowledge

- concepts specific to the investigation and explanation of their significance, including definitions of key terms, and physics representations
- characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including consideration of repeatability, reproducibility, reliability and validity of data, and identification of systematic error
- identification and application of relevant health and safety guidelines

- methods of organising, analysing and evaluating primary data: relevant descriptive statistics and their limitations; sources of uncertainty; limitations of data and methodologies
- use of models in organising and understanding observed phenomena and physics concepts, and their limitations
- key findings of the selected investigation and their relationship to key physics concepts
- nature of evidence that supports or refutes a hypothesis
- conventions of scientific report writing and scientific poster presentation, including correct physics language, symbols, equations, SI units of measurement, significant figures, representations, standard abbreviations, and correct acknowledgement of references.

SCHOOL-BASED ASSESSMENT

Satisfactory completion

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 assessment tasks to provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning and assessment activities.

Practical work and assessment

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 for each of Areas of Study 1 and 2. A practical investigation related to waves, fields or motion is to be undertaken either in Unit 3, in Unit 4, or across both Unit 3 and Unit 4, and will be assessed in Unit 4 as Outcome 3. The outcomes of the investigation will be presented in a scientific poster format. Between 7 and 10 hours of class time should be devoted to the investigation, including writing of the sections of the scientific poster.

Assessment of levels of achievement

The student's level of achievement in Unit 4 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be a part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. The VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and the assessment of student work for a level of achievement.

Teachers will provide to the VCAA a numerical score representing an assessment of the student's level of achievement.

The score must be based on the teacher's assessment of the performance of each student on the tasks set out in the following table.

Contribution to final assessment

School-assessed Coursework for Unit 4 will contribute 20 per cent to the study score.

Outcomes	Marks allocated*	Assessment tasks
Outcome 1 Apply wave principles to analyse, interpret and explain wave phenomena.	30	For Outcomes 1 and 2 At least one different task for each Outcome selected from: • annotations of at least two practical activities from a practical logbook • report of a student investigation • analysis of data including generalisations and conclusions • media analysis/response • extended response questions • reflective blog (approximately 50 minutes)
Outcome 2 Provide evidence for the nature of light and matter, and analyse the data from experiments that provide this evidence.	30	
Outcome 3 Design and undertake an investigation related to waves, fields or motion, and present methodologies, findings and conclusions as a scientific poster.	30	For Outcome 3: Structured scientific poster according to VCAA template (maximum 1000 words)
Total marks	**90**	

*School-assessed Coursework for Unit 4 contributes 20 per cent.

Unit 4 Outcome 3 – Investigation presented as a scientific poster

Unit 4 Outcome 3 requires that students communicate investigation findings as a scientific poster. The poster may be produced electronically or in hard copy format, and should not exceed 1000 words. Students must select information carefully so that they meet the word limit. The production quality of the poster will not form part of the assessment.

The following template provides details about construction of the poster by students and assessment of the poster by teachers.

Poster section	Key science skills from pages 9 and 10 of the study design	Poster section content	Marks
Title	select questions, formulate hypotheses and make predictions	Question under investigation is the title	required
Introduction		Explanation of reason for undertaking the investigation, including relevant background physics concepts	10
Hypothesis		Stated in 'If…then…' or other recognised format	5
Methodology	plan and undertake investigations	Clear methodology	10
	take into account safety and ethical considerations	Identification and management of risks: consideration of relevant health, safety and ethical guidelines	5
Results	conduct investigations to collect and record data	Data collection and recording in practical logbook	10
		Presentation of data in appropriate format to show trends, patterns or relationships	10
Discussion	analyse and evaluate data, methods and opinions	Analysis and evaluation of data	10
		Identification of outliers and their subsequent treatment	10
		Identification of limitations in data and methods, and suggested improvements	
	connect scientific ideas	Linking of results to relevant physics concepts	10
Conclusion	draw evidence-based conclusions	Conclusion that provides a response to the question	5
Throughout the poster	communicate scientific ideas	Correct use of scientific language, units, symbols and representations	10
		Clear, coherent, cogent expression	5

EXTERNAL ASSESSMENT

The level of achievement for Units 3 and 4 is also assessed by an end-of-year examination, which will contribute 60 per cent to the study score.

End-of-year examination

Description

The examination will be set by a panel appointed by the VCAA. All the key knowledge and key skills that underpin the outcomes in Units 3 and 4 are examinable.

Conditions

The examination will be completed under the following conditions:

- Duration: 2.5 hours.
- Date: end-of-year, on a date to be published annually by the VCAA.
- VCAA examination rules will apply. Details of these rules are published annually in the *VCE and VCAL Administrative Handbook*.
- The examination will be marked by assessors appointed by the VCAA.

Contribution to final assessment

The examination will contribute 60 per cent.

Further advice

The VCAA publishes specifications for all VCE examinations on the VCAA website. Examination specifications include details about the sections of the examination, their weighting, the question format/s and any other essential information. The specifications are published in the first year of implementation of the revised Units 3 and 4 sequence together with any sample material.