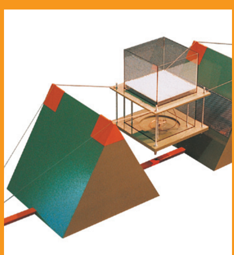
Accreditation period

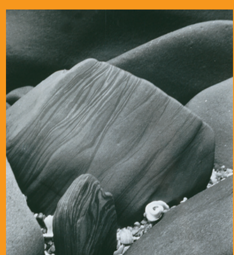
2013–2016

Physics

Victorian Certificate of Education **Study Design**





The images shown above represent a cross section of works covering sculpture, textiles, assemblage, drawing, photography, prints, painting and electronic media as exhibited in *VCE Top Arts.*

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Latoya BARTON
The sunset (detail)
from a series of twenty-four
9.0 x 9.0 cm each, oil on board

Tarkan ERTURK
Visage (detail)
201.0 x 170.0 cm
synthetic polymer paint, on cotton duck

Liana RASCHILLA
Teapot from the *Crazy Alice* set
19.0 x 22.0 x 22.0 cm
earthenware, clear glaze. lustres

Nigel BROWN
Untitled physics (detail)
90.0 x 440.0 x 70.0 cm
composition board, steel, loudspeakers, CD player, amplifier, glass

Kate WOOLLEY
Sarah (detail)
76.0 x 101.5 cm, oil on canvas

Chris ELLIS
Tranquility (detail)
35.0 x 22.5 cm
gelatin silver photograph

Christian HART
Within without (detail)
digital film, 6 minutes

Kristian LUCAS
Me, myself, I and you (detail)
56.0 x 102.0 cm
oil on canvas

Merryn ALLEN
Japanese illusions (detail)
centre back: 74.0 cm, waist (flat): 42.0 cm
polyester cotton

Ping (Irene VINCENT)
Boxes (detail)
colour photograph

James ATKINS
Light cascades (detail)
three works, 32.0 x 32.0 x 5.0 cm each
glass, flourescent light, metal

Tim JOINER
14 seconds (detail)
digital film, 1.30 minutes

Lucy McNAMARA
Precariously (detail)
156.0 x 61.0 x 61.0 cm
painted wood, oil paint, egg shells, glue, stainless steel wire

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Physics

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Contents

IMPORTANT INFORMATION

Accreditation period

Units 1–4: 2013–2016

The accreditation period commences on 1 January 2013.

Other sources of information

The *VCAA Bulletin VCE, VCAL and VET* is the only official source of changes to regulations and accredited studies. The Bulletin, including supplements, also regularly includes advice on VCE studies. It is the responsibility of each VCE teacher to refer to each issue of the Bulletin. The Bulletin is available on the Victorian Curriculum and Assessment Authority's website at www.vcaa.vic.edu.au

To assist teachers in assessing School-assessed Coursework in Units 3 and 4, the Victorian Curriculum and Assessment Authority publishes an assessment handbook that includes advice on the assessment tasks and performance descriptors for assessment.

The current *VCE and VCAL Administrative Handbook* contains essential information on assessment and other procedures.

VCE providers

Throughout this study design the term 'school' is intended to include both schools and other VCE providers.

Copyright

Introduction

RATIONALE

Physics is a theoretical and empirical science, which contributes to our understanding of the physical universe from the minute building blocks of matter to the unimaginably broad expanses of the Universe. This understanding has significance for the way we understand our place in the Universe.

This study is designed to enhance the scientific literacy of students in the specialised area of physics. Scientifically literate physics students demonstrate interest in and understanding of the Universe, engage in debates about the nature of evidence, theories and models, and appreciate the value of physics in society. They can describe and use theories and models, propose and investigate hypotheses, collect data, analyse the limitations of that data, draw conclusions, make recommendations, and select and use a range of appropriate technologies and mathematical techniques.

The knowledge gained through physics will enhance students' ability to be innovative and contribute to the intelligent and careful use of resources. This knowledge can be used, for example, in industrial, medical, engineering and technical applications.

Knowledge in physics is gained through complex processes; for example, theories developed from studying the ways that matter interacts with matter, and the ways that light and matter interact, have led to innovations in medicine, electronics, energy use, telecommunications and materials science.

This study design will assist teachers to provide a curriculum that is interesting and challenging for students with a wide range of expectations, including students who are aiming for medical, engineering, technology-based and science-based careers.

AIMS

This study is designed to enable students to:

- develop the language, methodology and major ideas of physics
- understand the ways knowledge is extended, organised and revised in physics, in particular the role of conceptual and mathematical models applied to physical phenomena
- identify and assess the validity and reliability of underlying assumptions and/or limitations of models, data, and conclusions

- develop skills in the design and conduct of practical investigations including data collection, analysis and critical evaluation of conclusions, and in the application of safe, responsible and ethical work practices
- identify alternative interpretations of results
- communicate effectively the results of their research and investigations
- understand applications of physics to technology, especially socially and economically significant developments
- acquire knowledge and skills that prepare them for careers in physics and related fields of science and technology
- understand emerging technologies, including the use of information and communications technology, in communication, experimental data acquisition and analysis.

STRUCTURE

The study is made up of four units. Each unit contains two prescribed areas of study and a third area of study to be selected from the list of detailed studies available in Units 1 to 4.

Each unit deals with specific content and is designed to enable students to achieve a set of outcomes. Each outcome is described in terms of key knowledge and application of key skills.

A table defining the use of verbs across Units 1 to 4 in the Physics study design is included on pages 44–45 under ‘Advice for teachers’.

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 curriculum.

DURATION

Each unit involves at least 50 hours of scheduled classroom instruction.

CHANGES TO THE STUDY DESIGN

During its period of accreditation minor changes to the study will be announced in the *VCAA Bulletin VCE, VCAL and VET*. The Bulletin is the only source of changes to regulations and accredited studies and 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 Victorian Curriculum and Assessment Authority will periodically undertake an audit of 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 during the teaching year of schools and studies to be audited and the required material for submission.

SAFETY

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).

USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY

In designing courses for this study teachers should incorporate information and communications technology where appropriate and applicable to the teaching and learning activities. The 'Advice for teachers' section provides specific examples of how information and communications technology can be used in this study.

EMPLOYABILITY SKILLS

This study offers a number of opportunities for students to develop employability skills. The 'Advice for teachers' section 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 a decision that the student has demonstrated achievement of the set of outcomes specified for the unit. This decision will be based on the teacher's assessment of the student's performance on assessment tasks designated for the unit. Designated assessment tasks are provided in the details for each unit. The Victorian Curriculum and Assessment Authority publishes an assessment handbook that includes advice on the assessment tasks and performance descriptors for assessment for Units 3 and 4.

Teachers must develop courses that provide opportunities for students to demonstrate achievement of outcomes. Examples of learning activities are provided in the 'Advice for teachers' section.

Schools will report a result for each unit to the Victorian Curriculum and Assessment Authority as S (Satisfactory) or N (Not Satisfactory).

Completion of a unit will be reported on the Statement of Results issued by the Victorian Curriculum and Assessment Authority as S (Satisfactory) or N (Not Satisfactory). Schools may report additional information on levels of achievement.

AUTHENTICATION

Work related to the outcomes 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.

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 Victorian Curriculum and Assessment Authority. Schools may choose to report levels of achievement using grades, descriptive statements or other indicators.

Units 3 and 4

The Victorian Curriculum and Assessment Authority will supervise the assessment of all students undertaking Units 3 and 4.

In the study of Physics the student's level of achievement will be determined by School-assessed Coursework and an end-of-year examination. The Victorian Curriculum and Assessment Authority will report the student's level of performance on each assessment component as a grade from A+ to E or UG (ungraded). To receive a study score, students 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 year's *VCE and VCAL Administrative Handbook* for details on graded assessment and calculation of the study score. Percentage contributions to the study score in Physics are as follows:

- Unit 3 School-assessed Coursework: 16 per cent
- Unit 4 School-assessed Coursework: 24 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.

Units 1–4: Key skills

In the study of Physics a set of key skills is considered essential. These skills apply across Units 1 to 4. In designing teaching and learning programs for each unit, teachers must ensure that students are given the opportunity to develop and apply these skills in a variety of contexts. As the complexity of key knowledge increases from Units 1 through to 4, students should demonstrate the key skills at a progressively higher level.

The key skills are:

Investigate and inquire scientifically

- identify and select questions for investigation, formulating hypotheses and identifying and addressing possible sources of uncertainty
- design and conduct first-hand investigations that include collecting, processing, recording, analysing, synthesising and evaluating qualitative and quantitative data
- select and use equipment and materials appropriate to the investigation
- draw conclusions consistent with the question under investigation and the information collected, identifying errors and evaluating investigative procedures and reliability and accuracy of data
- identify and apply safe and responsible work practices when designing and completing independent or collaborative investigations.

Analyse and apply physics understanding

- identify and describe relevant scientific information, ideas and concepts, and the connections between them
- select first-hand and second-hand data and evidence to demonstrate how physics concepts, theories and models have developed and been modified over time
- explain how models are used by physical scientists to organise and understand observed phenomena, identifying limitations of the models
- apply graphical, numerical and algebraic models to first-hand data collected during practical investigations, and to second-hand data
- model scientific ideas and processes
- calculate quantities and analyse and solve qualitative and quantitative problems
- apply understanding of concepts to explain qualitative and quantitative data in both familiar and new contexts
- identify and explain alternative interpretations of qualitative and quantitative data
- analyse issues and implications for humans and the environment relating to scientific and technological developments
- analyse and evaluate the reliability of physics-related information and opinions presented in the public domain.

Communicate physics information and understanding

- interpret, explain and communicate physics data, information and ideas accurately and effectively, using communication modes appropriate for different audiences and purposes
- apply scientific language and conventions correctly, including scientific formulas, symbols, equations and units of measurement.

Unit 1

This unit focuses on Physics as a human endeavour. Observations and ideas about the physical world related to aspects of energy are organised and explained through the use of conceptual models. The detailed studies provide opportunities to explore the application of energy concepts and models in nuclear energy, sustainable energy sources, flight, space and medical contexts.

Students undertake regular experimental work in the laboratory starting with simple observations and measurements. A quantitative investigation involving the collection and analysis of sufficient data points for at least one independent variable will be undertaken. The investigation should be at least partly student designed.

The use of simple mathematical modelling, including calculations, is introduced to organise first-hand and second-hand data in order to make predictions and link concepts. Students begin to solve qualitative and quantitative problems in familiar contexts. Computer and/or graphics calculator programs are used to collect and analyse first-hand and second-hand data and to present investigation findings.

Unit 1 consists of two prescribed areas of study: Nuclear physics and radioactivity; and Electricity; and a third area of study to be chosen from one of six detailed studies: Astronomy, Astrophysics, Energy from the nucleus, Investigations: Flight, Investigations: Sustainable energy sources, and Medical physics.

In this unit, students make and test predictions, identify discrete and continuous variables, select relevant independent variables and recognise controlled variables. They apply a given method for a simple investigation to control variables and collect relevant data. Students record raw qualitative and quantitative data and present processed data, including correct use of units, symbols and formulas, appropriately. They use suitable materials, apparatus and measurement procedures to ensure reliability in the data. When drawing relevant conclusions from their investigations, students recognise sources of uncertainty and error. When completing independent and collaborative investigations, they identify alternative interpretations of data and results. They use appropriate sources to identify and assess risks to themselves, other living things and the environment of Physics related principles and procedures, and they use this knowledge to apply safe, ethical and responsible practices.

As a guide, at least 10 hours of class time should be devoted to student practical work across the three areas of study.

AREA OF STUDY 1

Nuclear physics and radioactivity

The particle model of matter and ideas about energy transfers and transformations are relevant to the study of nuclear physics and radioactivity.

Students' understanding of the particle model of matter, developed in earlier years, is extended to include subatomic particles.

Ideas of energy transfer and transformations are applied to energy changes associated with nuclear phenomena and radioactivity, and their applications.

Students develop knowledge and skills to contribute to informed debate on the use of nuclear and radioactive technological applications in society.

Students will use the concepts of nuclear physics and radioactivity in the contexts of environmental radiation and the production and use of radioisotopes in industry. They will access information related to the use of nuclear reactions and radioactivity.

Outcome 1

On completion of this unit the student should be able to explain and model relevant physics ideas to describe the sources and uses of nuclear reactions and radioactivity and their effects on living things, the environment and in industry.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- explain why some atomic nuclei are stable and others are not
- describe the radioactive decay of unstable nuclei in terms of half-life
- model radioactive decay as random decay with a particular half-life, including mathematical modelling in terms of whole half-lives
- apply a simple particle model of the atomic nucleus to the origin of α, β and γ radiation, including changes to the number of nucleons
- describe the detection and penetrating properties of α, β and γ radiation
- describe the effects of α, β and γ radiation on humans, including short- and long-term effects from low and high doses, external and internal sources, including absorbed dose (Gray), equivalent dose (Sieverts) and effective dose (Sieverts)
- describe the effects of ionising radiation on living things and the environment
- explain nuclear transformations using decay equations involving α, β and γ radiation
- analyse decay series diagrams in terms of type of decay and stability of isotopes
- describe natural and artificial isotopes in terms of source and stability
- describe neutron absorption as one means of production of artificial radioisotopes
- identify sources of bias and error in written and other media related to nuclear physics and radioactivity
- describe the risks for living things and/or the environment associated with the use of nuclear reactions and radioactivity.

AREA OF STUDY 2

Electricity

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. Mathematical models are applied and critically assessed during experimental investigation of DC circuits.

Students will use electrical circuits in the contexts of simple battery operated DC devices, household electricity, and car electrical systems.

For further information about safety in practical situations, see 'Safety' on page 9.

Outcome 2

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

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- apply the concepts of charge (Q), electric current (I), potential difference (V), energy (E) and power (P), in electric circuits
- analyse electrical circuits using the relationships $I = Q/t$, $V = E/Q$, $P = E/t = VI$, $E = VIt$
- model resistance in series and parallel circuits using
  - potential difference versus current (V-I) graphs
  - resistance as the potential difference to current ratio, including $\frac{V}{I} = R$ = constant for ohmic devices
  - equivalent effective resistance in arrangements in
    - series: $R_T = R_1 + R_2 + ... + R_n$ and
    - parallel: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_n}$
- model simple electrical circuits such as car and household (AC) electrical systems as simple direct current (DC) circuits
- model household electricity connections as a simple circuit comprising fuses, switches, circuit breakers, loads and earth
- identify causes, effects and treatment of electric shock in homes, relating these to approximate danger thresholds for current and time
- investigate practically the operation of simple circuits containing resistors, variable resistors, diodes and other non-ohmic devices
- convert energy values to kilowatt-hour (kWh)
- evaluate the risk in the use of electrical equipment and power supplies using relevant data
- identify and apply safe and responsible practices when conducting investigations involving electrical equipment and power supplies.

AREA OF STUDY 3

Detailed study

Six detailed studies are available for selection in Unit 1. One detailed study is to be selected from:

- Astronomy
- Astrophysics
- Energy from the nucleus
- Investigations: Flight
- Investigations: Sustainable energy sources
- Medical physics.

The outcome and key knowledge for each detailed study are described in detail on pages 21 to 25.

The selected detailed study requires approximately 12 hours of class time.

Note: The detailed study chosen in Unit 1 must be a different detailed study from that chosen in Unit 2.

ASSESSMENT

The award of satisfactory completion for a unit is based on a decision that the student has demonstrated achievement of the set of outcomes specified for the unit. This decision will be based on the teacher's assessment of the student's overall performance on assessment tasks designated for the unit.

The key knowledge listed for each outcome and application of key skills should be used as a guide to course design and the development of learning activities. The key knowledge and application of key skills do not constitute a checklist and such an approach is not necessary or desirable for determining the achievement of outcomes. The elements of key knowledge and application of key skills should not be assessed separately.

Assessment 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. Teachers should select a variety of assessment tasks for their assessment program to reflect the key knowledge and application of key skills being assessed and to provide for different learning styles.

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

Demonstration of achievement of Outcomes 1, 2 and one of 3.1, 3.2, 3.3, 3.4, 3.5 or 3.6 must be based on the student's performance on a selection of assessment tasks. Where teachers allow students to choose between tasks they must ensure that the tasks they set are of comparable scope and demand.

Assessment tasks for this unit are:

A practical investigation (student designed or adapted)

and

A selection from the following:

- an annotated folio of practical activities
- a data analysis
- a multimedia or web page presentation
- a response to a media article
- a summary report of selected practical investigations including maintenance of a logbook
- a written report
- a test (short answer and extended response).

Unit 2

This unit focuses on the application of models to more complex phenomena – motion and light – developed within contexts that are familiar to students and relevant to their experiences. Newtonian ideas of motion are extended to include a range of movements and more abstract ideas, while the wave and particle models of light provide a framework for exploring light phenomena in real world applications. The detailed studies provide opportunities to explore motion and/or light in nuclear, sustainable energy, flight, space and medical contexts.

Students continue to undertake extensive and regular experimental work in the laboratory. They design and undertake more complex investigations involving at least one independent, continuous variable, and take increasing responsibility for the design of investigations.

The use of simple mathematical modelling, including calculations, to organise first-hand and second-hand data, to make predictions and to link concepts is further developed and applied to more extensive data. Students begin to analyse and solve quantitative and qualitative problems in familiar contexts. Computer and graphics calculator programs are used to collect and analyse first-hand and second-hand data, and to present investigation findings.

Unit 2 consists of two prescribed areas of study: Motion and Wave-like properties of light; and a third area of study to be chosen from one of six detailed studies: Astronomy, Astrophysics, Energy from the nucleus, Investigations: Flight, Investigations: Sustainable energy sources and Medical physics. The detailed study chosen in Unit 2 must be a different detailed study from that chosen in Unit 1.

In this unit, students identify a problem or research question and formulate a prediction or hypothesis, select at least one relevant independent continuous variable and recognise controlled variables. They adapt or extend given methods, or at least partly design their own methods, for the control of variables and the systematic collection and recording of sufficient relevant data for simple investigations.

Students record raw qualitative and quantitative data and present processed data, including correct use of units, symbols and formulas, appropriately. They select and use appropriate materials, apparatus and measurement procedures to ensure reliability in the data. When drawing relevant conclusions from their investigations, students take into account sources of error and uncertainty. They evaluate limitations of, and weaknesses and errors in, techniques and equipment. Alternative interpretations of data and results are identified. Students identify and apply safe and responsible practices when completing independent and collaborative investigations. They use appropriate information sources to assess risk.

As a guide, at least 10 hours of class time should be devoted to student practical work across the three areas of study.

AREA OF STUDY 1

Motion

Students learn about the models used to explain motion from the early theories of Aristotle and the work of Galileo and Newton. These theories are developed through the examination of aspects of motion including transport, games and sport.

All models should be developed within contexts that are familiar and relevant to students. Ideas about energy transfers and transformations continue to be used. Mathematical models are critically applied during experimental investigations of examples of motion.

Students will study the historical development of the Newtonian model of motion and apply it in the contexts of transport, games and sport.

In this study students will assume that the mass of finite objects can be considered to be at a point: the centre of mass.

Outcome 1

On completion of this unit the student should be able to investigate, analyse and mathematically model motion of particles and bodies in terms of Aristotelian, Galilean and Newtonian theories.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- identify parameters of motion as vectors or scalars
- analyse straight-line motion under constant acceleration graphically, numerically and algebraically
- analyse graphically non-uniform motion in a straight line
- compare the effect of a force as defined by Aristotle, Galileo and Newton
- describe the change in motion that results from the application of a force
- model weight, w, as the force of gravity acting at the centre of mass point (approximated as the geometric centre) of a body, $w = mg$
- model forces as vectors acting at the point of application (with magnitude and direction), labelling these forces using the convention 'force of … on …'
- apply Newton's three laws of motion to a body on which a resultant vector force acts
- apply the vector model of forces, including vector addition and components of forces, to readily observable forces including weight, friction and reaction forces
- apply the concept of work done by a constant force
  - work done = constant force x distance moved in direction of force
  - work done = area under force-distance graph
- analyse Hooke's Law for an ideal spring, $F=-k\Delta x$
- analyse energy transfers and transformations using an energy conservation model including transfers between
  - gravitational potential energy *near* Earth's surface, $mg\Delta h$, and kinetic energy, $\frac{1}{2}mv^2$
  - potential energy in ideal springs, $\frac{1}{2}k\Delta x^2$, and kinetic energy, $\frac{1}{2}mv^2$
- apply rate of energy transfer, power, $P = E/t$
- apply the concept of momentum, $p = mv$
- describe how action of a net force causes changes in momentum

- analyse impulse (momentum transfer) in an isolated system, for elastic collisions between objects moving in a straight line
- apply graphical, numerical and algebraic models to primary data collected during practical investigations of motion, and to secondary data
- identify and apply safe and responsible practices when investigating motion.

AREA OF STUDY 2

Wave-like properties of light

Light phenomena are examples of the interaction of the physical world with human biology. The wave model of light, compared with the particle model of light, will be evaluated in terms of satisfactorily explaining light phenomena.

Students will use the wave-like properties of light in the contexts of seeing with the unaided eye, extending visual and communication capabilities, and special theatrical effects.

Outcome 2

On completion of this unit the student should be able to describe and explain the wave model of light, compare it with the particle model of light and apply it to observed light phenomena in practical investigations.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- describe transverse waves in terms of
  - amplitude
  - wavelength
  - period and frequency
- calculate wavelength, frequency, period and speed of travel of light waves, $v = f\lambda = \lambda/T$
- investigate and analyse the behaviour of light using ray diagrams including
  - reflection, $i = r$
  - refraction, Snell's Law
  - total internal reflection, critical angle

  (any form of image location is not required)
- describe light using a wave model and a particle model
- explain polarisation of visible light and its relation to a transverse wave model
- compare the wave model and the particle model of light in terms of whether they adequately describe reflection and refraction
- identify visible light as a particular region of the spectrum of electromagnetic radiation and that all light travels at the speed of light in a vacuum, c
- explain the colour components of white light as different frequencies of light combining to appear white
- 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
- identify and apply safe and responsible practices when working with light sources and optical devices.

AREA OF STUDY 3

Detailed study

Six detailed studies are available for selection in Unit 2. The detailed study chosen in Unit 2 must be a different detailed study from that chosen in Unit 1. One detailed study is to be selected from:

- Astronomy
- Astrophysics
- Energy from the nucleus
- Investigations: Flight
- Investigations: Sustainable energy sources
- Medical physics.

The outcome and key knowledge for each detailed study are described in detail on pages 21 to 25.

The selected detailed study requires approximately 12 hours of class time.

ASSESSMENT

The award of satisfactory completion for a unit is based on a decision that the student has demonstrated achievement of the set of outcomes specified for the unit. This decision will be based on the teacher's assessment of the student's overall performance on assessment tasks designated for the unit.

The key knowledge listed for each outcome and application of key skills listed for each outcome should be used as a guide to course design and the development of learning activities. The key knowledge and application of key skills do not constitute a checklist and such an approach is not necessary or desirable for determining the achievement of outcomes. The elements of key knowledge and application of key skills should not be assessed separately.

Assessment 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. Teachers should select a variety of assessment tasks for their assessment program to reflect the key knowledge and application of key skills being assessed and to provide for different learning styles.

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

Demonstration of achievement of Outcomes 1, 2 and one of 3.1, 3.2, 3.3, 3.4, 3.5 or 3.6 must be based on the student's performance on a selection of assessment tasks. Where teachers allow students to choose between tasks they must ensure that the tasks they set are of comparable scope and demand.

Assessment tasks for this unit are:

A practical investigation (student designed, adapted or extended)

and

A selection from the following:

- an annotated folio of practical activities
- a data analysis
- a multimedia or web page presentation
- a response to a media article
- a summary report of selected practical investigations including maintenance of a logbook
- a written report
- a test (short answer and extended response).

DETAILED STUDIES FOR UNITS 1 AND 2

Detailed study 3.1: Astronomy

This detailed study enables students to understand the modern interpretation of the Universe as we see it. Humans have long constructed models of the solar system and more recently, the entire Universe. Students examine the ways in which our present model has developed from those of the early Greeks, through the Enlightenment to modern times. The development of modern telescopes, both optical and radio, has enabled astronomers to develop new insights and theories about the origins of the Universe, starting from the simple observations we can make from our own backyard at night, to the observations of astronomers using sophisticated modern instruments.

Students will use the observations of astronomy in the context of the historical development of our picture of the Universe and our place in it.

Outcome 3.1

On completion of this unit the student should be able to use observations to explain the motions of stars and planets, and describe models of planetary motion.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- interpret the positions of some observed celestial objects as a function of time of day and time of year on a standard grid, for example altitude–azimuth, right ascension–declination
- explain the diurnal and annual motion of the stars and planets as seen from Earth
- explain telescopic observations of changes to celestial objects (including planets) such as relative position or physical appearance
- describe early geocentric models of the Universe and the epicycle orbits of the planets, including Ptolemy's model as it applies to Mars
- describe the Copernican heliocentric model of the solar system
- describe Galileo's telescopic observations of the positions of the Moon, Sun, Jupiter and Venus with reference to his heliocentric interpretation
- explain how the development of the telescope enabled the discovery of planets, asteroids, comets, nebulae, galaxies and black holes
- evaluate telescopes, for example commonly available and space-based telescopes, according to their purpose, optical system (reflecting, refracting), mount (altazimuth, equatorial), data collection system (optical, electronic) and quality of image in terms of aberration (spherical, chromatic)
- interpret and apply appropriate data relevant to aspects of astronomy from a database
- identify and apply safe and responsible practices when using equipment to make celestial observations.

Detailed study 3.2: Astrophysics

This detailed study focuses on the development of cosmology over time, but with a particular emphasis on the twentieth century. In particular, the study looks at the nature of stars, galaxies and their evolution, as well as evidence about the steady state and 'Big Bang' models of the Universe.

Light is the basic tool of astrophysicists and it is assumed that the nature of the nuclear atom is the same throughout the Universe. While Einstein's relativity is needed for the details, the Newtonian understanding of motion is sufficient to establish the basic ideas.

Students will use astrophysics in the contexts of astronomy, and theories of the nature and origin of the Universe.

Outcome 3.2

On completion of this unit the student should be able to describe and explain methods used to gather information about stars and other astronomical objects and apply this information to models of the nature and origin of the Universe.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- describe characteristics of the Sun as a typical star, including size, mass, energy output, colour and information obtained from the Sun's radiation spectrum
- describe the properties of stars: luminosity, radius and mass, temperature and spectral type
- explain fusion as the energy source of a star
- apply information from the Hertzsprung–Russell diagram to describe the evolution and death of stars with differing initial mass
- analyse methods used for measurements of the distances to stars and galaxies
- explain the link between the Doppler Effect and Hubble's observations
- explain the formation of galaxies, stars, and planets
- compare the Milky Way galaxy to other galaxies such as those with different shape, colour or size
- explain the steady state and Big Bang models of the Universe
- compare two or more explanations of the nature and origin of the Universe
- interpret and apply appropriate data from a database that is relevant to aspects of astrophysics.

Detailed study 3.3: Energy from the nucleus

This detailed study develops students' understanding of models of nuclear transformation and their capacity to evaluate critically the use of nuclear technologies. The energy available from fusing the nuclei of small atoms supplies the radiant energy of stars, including Earth's ultimate energy source, the Sun. The fusion process is also undergoing extensive investigation as an energy source. Splitting large nuclei has already been used to provide energy for domestic and commercial use. The use of nuclear energy technology, however, raises the challenge of balancing its benefits against the risks associated with both the operation of nuclear power stations and the disposal of radioactive waste.

Students will use nuclear transformations in the contexts of energy from stars, and nuclear technologies, and will access information related to the use of nuclear energy.

Outcome 3.3

On completion of this unit the student should be able to describe and explain typical fission and fusion reactions, energy transfer and transformation phenomena of importance in stars and in the production of nuclear energy, and the benefits and risks of the use of nuclear energy as a power source for society.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- explain the structure of the atom in terms of
  - location of protons, neutrons and electrons
  - electrostatic forces
  - strong nuclear forces in the nucleus
  - the stability of nuclei of different size
- describe fission and fusion reactions in terms of balance of energy, $E = mc^2$
- explain nuclear fusion phenomena, including ^{1}H and ^{2}H, in terms of
  - conditions required for fusion reactions including the large kinetic energy of the nuclei required to initiate nuclear fusion
  - energy released
- 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
- describe the energy transfers and transformations in the systems that convert nuclear energy into thermal energy for subsequent power generation
- evaluate the risks and benefits for society of using nuclear energy as a power source.

Detailed study 3.4: Investigations: Flight

This detailed study allows students to apply skills of experimental investigation to the task of designing, carrying out and reporting on a practical investigation into an aspect of flight.

Conceptual models of Newton and Bernoulli are applied by aircraft designers to every type of aircraft. Designers are then able to determine such things as the overall shape of the aircraft, how many engines are required, how far it can go, and how long a runway is needed.

Students will use conceptual models of Newton and Bernoulli in the context of flight.

Outcome 3.4

On completion of this unit the student should be able to design, perform and report on an experimental investigation related to an aspect of flight, and to explain results and conclusions by including reference to Newton's laws of motion and Bernoulli's principle.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- apply the concepts of forces, torques and equilibrium to balancing an aircraft, including reference to Newton's laws of motion
- explain lift in terms of Bernoulli's principle and the rate of change of momentum
- model lift and Bernoulli's principle using a wind tunnel
- explain drag, skin friction drag, pressure drag and principles of thrust
- investigate experimentally the relationship between power and thrust

- analyse aircraft performance including takeoff, climb, descent and cruise, with reference to Newton's laws of motion and Bernoulli's principle
- investigate experimentally identified aspects of performance using a model
- analyse risks in the use and testing of flying models using relevant data
- identify and apply safe and responsible practices when using and testing flying models.

Detailed study 3.5: Investigations: Sustainable energy sources

This detailed study enables students to investigate the potential for the development and implementation of a renewable energy resource to provide a portion of our energy needs.

Students will simulate an energy supply system through development of a working model or computer simulation program, and conduct a series of investigations that would provide quantitative data on the performance of the system. Performance data, in conjunction with research into the selected system, should be extrapolated into a review of its potential for larger scale commercial implementation.

Students will use concepts of energy transfer and energy transformations in either the context of a solar thermal system (either active or passive) or an electrical generation system (for example, photovoltaic, wind, hydroelectric, tidal, wave).

Outcome 3.5

On completion of this unit the student should be able to use concepts of energy transfer and transformations to design, conduct and report on an experimental investigation into an aspect of a renewable energy supply system.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- explain the terms sustainable and renewable in terms of energy use
- compare different renewable energy sources and investigate one experimentally
- analyse the potential of the system being investigated to make a significant contribution to the community's energy requirements, including the benefits, limitations and environmental consequences of the system
- design an experimental investigation that models energy transfer and transformation processes of the system
- analyse energy transfer and transformation processes of the system
- calculate the efficiency of the energy transfer and transformation processes of the system
- describe the operation of the system in terms of energy transfer and transformation processes
- evaluate the model system in relation to a real-life problem involving energy supply
- interpret information sources to evaluate risks in the development and use of an energy supply system
- identify and apply safe and responsible practices in the development and use of an energy supply system.

Detailed study 3.6: Medical physics

This detailed study extends the study of radioactivity and wave phenomena to applications in medical diagnosis and treatment.

Students will use radioactivity and waves in the context of applications in medical diagnosis and treatment.

Outcome 3.6

On completion of this unit the student should be able to describe and explain applications of radioisotopes, optical fibres, waves and lasers to medical diagnosis and treatment, and describe the production and/or simple interpretation of images of the human body produced by the processes of CT, ultrasound or X-rays.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- describe applications of radioisotopes to medical diagnosis and treatment
- explain the use and operation of optical fibres in endoscopes and in other applications for diagnosis and treatment
- describe and evaluate the use of lasers as intense energy sources for medical treatments
- describe and compare processes of, and images produced by, medical imaging using two or more of ultrasound, X-rays, CT, MRI and PET
- identify and apply safe and responsible practices when working with radioactive material and completing investigations.

Unit 3

Unit 3 consists of two prescribed areas of study: Motion in one and two dimensions; and Electronics and photonics. A detailed study is to be chosen in either Unit 3 or Unit 4 from one of six detailed studies: Einstein's special relativity, Materials and their use in structures, Further electronics, Synchrotron and its applications, Photonics, and Sound.

This unit focuses on the ideas that underpin much of the technology found in areas such as communications, engineering, commerce and industry. Motion in one and two dimensions is introduced and applied to moving objects on Earth and in space. Circuit models are applied to further aspects of electricity and electronics, and the operation and use of photonic devices are introduced. The detailed studies offer examples of theoretical and practical applications of these technologies.

Students continue to have regular experience in experimental investigation in the laboratory. They design and carry out an extended practical investigation. They collect accurate data, evaluate the quality of data and measurement processes, and make conclusions based on the data.

Mathematical modelling, including calculations, is applied to all areas of study to organise first-hand and second-hand data, make predictions and link concepts. Students analyse and solve more complex qualitative and quantitative problems.

Computer and/or graphics calculator programs are used to collect and analyse first-hand and second-hand data, and to present investigation findings.

In this unit, students select focused research questions and formulate a quantitatively testable hypothesis. They identify variables of significance to an investigation and decide the appropriate variables to be controlled. They adapt or extend given methods, and design their own methods, for the control of variables and the systematic collection of sufficient relevant data for focused investigations.

Students record raw qualitative and quantitative data accurately and present processed data, including correct use of units, symbols and formulas, to ensure that relationships between variables are evident. They select and use appropriate materials, apparatus and measurement procedures to ensure a high degree of reliability and accuracy in the data. Students interpret their results to draw relevant conclusions from their investigations. They identify sources of error and estimate uncertainties in, and reliability of, data and derived quantities. They analyse procedures and results, taking into account limitations of, and weaknesses and errors in, techniques and equipment. Alternative interpretations of data and results are identified and explained. They identify and apply safe and responsible practices when designing and completing independent and collaborative investigations. Students select and use appropriate information sources to assess risk.

As a guide, between 3½ and 5 hours of class time should be devoted to student practical work for each prescribed area of study and between 3½ and 5 hours of class time should be devoted to student practical work for the detailed study if undertaken in Unit 3.

AREA OF STUDY 1

Motion in one and two dimensions

Newtonian theories give important insights into a range of motions and contribute towards safety considerations. This study should focus on everyday motion that is relevant, familiar and interesting to students.

Newton's insight into gravity has led to understanding of the motion of the solar system, the achievements of space travel, and satellite technology.

Students will use the Newtonian laws of motion in the contexts of transport and safety on Earth, and motion in space.

Outcome 1

On completion of this unit the student should be able to investigate motion and related energy transformations experimentally, and use the Newtonian model in one and two dimensions to analyse motion in the context of transport and related aspects of safety, and motion in space.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- 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 ($F_{net} = mv^2/R$) such as a vehicle moving around a circular road; a vehicle moving around a banked track; an object on the end of a string
- apply Newton's second law to circular motion in a vertical plane; consider forces at the highest and lowest positions only
- investigate and analyse the motion of projectiles near Earth's surface including a qualitative description of the effects of air resistance
- apply laws of energy and momentum conservation in isolated systems
- analyse impulse (momentum transfer) 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
  - 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, that is, $½mv^2$; 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, $½kx^2$
  - gravitational potential energy, that is, $mg\Delta h$ or from area under force-distance graph and area under field-distance graph multiplied by mass
- apply gravitational field and gravitational force concepts, $g = GM/r^2$ and $F = GM_1M_2/r^2$
- apply the concepts of weight (W=mg), apparent weight (reaction force, N), weightlessness (W=0) and apparent weightlessness (N=0)

- model satellite motion (artificial, moon, planet) as uniform circular orbital motion ($a = v^2/r = 4\pi^2 r/T^2$)
- identify and apply safe and responsible practices when working with moving objects and equipment in investigations of motion.

AREA OF STUDY 2

Electronics and photonics

Photonics is the science of using light to manipulate information and energy and involves all facets of visible, ultraviolet and infrared radiation; this includes its detection, transport, storage and manipulation. Photonics is the basis of much of modern communication technology. Photonic devices are used with electronic components in smoke detectors, burglar alarms, safety interlocks, televisions, cathode ray oscilloscopes, relative position sensors, communication devices including fibre optic cables, modulators and demodulators, CD readers and writers, and computer networks. Some phenomena which characterise the interface between electronics and photonics are introduced.

Students will use electronic and photonic devices and systems in domestic and industrial contexts. For further information about safety, see ‘Safety’ on page 9.

Outcome 2

On completion of this unit the student should be able to investigate, describe, compare and explain the operation of electronic and photonic devices, and analyse their use in domestic and industrial systems.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- apply the concepts of current, resistance, potential difference (voltage drop) and power to the operation of electronic circuits comprising diodes, resistors, thermistors and photonic transducers including light dependent resistors (LDR), photodiodes and light emitting diodes (LED), ($V=IR$, $P=VI$)
- calculate the effective resistance of circuits comprising parallel and series resistance and unloaded voltage dividers
- describe energy transfers and transformations in opto-electronic devices
- describe the transfer of information in analogue form (excluding the technical aspects of modulation and demodulation) using the principles of:
  - light intensity modulation, that is, changing the intensity of the carrier wave to replicate the amplitude variation of the information signal so that the signal may propagate more efficiently
  - demodulation, that is, the separation of the information signal from the carrier wave
- design, investigate and analyse circuits for particular purposes using technical specifications related to potential difference (voltage drop), current, resistance, power, temperature and illumination for electronic components such as diodes, resistors, thermistors, light dependent resistors (LDR), photodiodes and light emitting diodes (LED)
- analyse voltage characteristics of amplifiers including linear voltage gain ($\Delta V_{out}/\Delta V_{in}$) and clipping
- identify and apply safe and responsible practices when conducting investigations involving electrical, electronic and photonic equipment.

ASSESSMENT

The award of satisfactory completion for a unit is based on a decision that the student has demonstrated achievement of the set of outcomes specified for the unit. This decision will be based on the teacher's assessment of the student's overall performance on assessment tasks designated for the unit. The Victorian Curriculum and Assessment Authority publishes an assessment handbook that includes advice on the assessment tasks and performance descriptors for assessment.

The key knowledge listed for each outcome and application of key skills should be used as a guide to course design and the development of learning activities. The key knowledge and application of key skills do not constitute a checklist and such an approach is not necessary or desirable for determining the achievement of outcomes. The elements of key knowledge and application of key skills should not be assessed separately.

Assessment of levels of achievement

The student's level of achievement in Unit 3 will be determined by School-assessed Coursework and an end-of-year examination.

Contribution to final assessment

School-assessed Coursework for Unit 3, not including assessment of the detailed study, will contribute 16 per cent to the study score.

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.

School-assessed Coursework

Teachers will provide to the Victorian Curriculum and Assessment Authority a score representing an assessment of the student's level of achievement.

The score must be based on the teacher's rating of performance of each student on the tasks set out in the following table and in accordance with the assessment handbook published by the Victorian Curriculum and Assessment Authority. The assessment handbook also includes advice on the assessment tasks and performance descriptors for assessment.

Assessment 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 optional assessment tasks are used, teachers must ensure that they are comparable in scope and demand. Teachers should select a variety of assessment tasks for their program to reflect the key knowledge and application of key skills being assessed and to provide for different learning styles.

Outcomes	Marks allocated*	Assessment tasks
Outcome 1 Investigate motion and related energy transformations experimentally, and use the Newtonian model in one and two dimensions to analyse motion in the contexts of transport and related aspects of safety, and motion in space.	40	At least two different tasks selected from the following:** • a student-designed extended practical investigation • a summary report of selected practical activities from the student's log book • a multimedia presentation • a data analysis • a report (written, oral, annotated visual) • a test (short answer and extended response) • a response to a media article.
Outcome 2 Investigate, describe, compare and explain the operation of electronic and photonic devices, and analyse their use in domestic and industrial systems.	30	
Detailed study One detailed study is to be chosen in either Unit 3 or Unit 4, and will contribute to the study score at Unit 4.		**Across the assessment tasks selected in Unit 3 and 4, at least one of the assessment tasks must be an extended practical investigation and at least one of the assessment tasks must be a summary report of selected practical activities.
Total marks	**70**	

*School-assessed Coursework for Unit 3 contributes 16 per cent to the study score.

Unit 4

Unit 4 consists of two prescribed areas of study: Electric power and Interactions of light and matter. A detailed study is to be chosen in either Unit 3 or Unit 4 from one of six detailed studies: Einstein's special relativity, Materials and their use in structures, Further electronics, Synchrotron and its applications, Photonics, and Sound.

This unit focuses on the development and limitations of models in explaining physical phenomena. A field model of electromagnetism is applied to the generation of electricity, and the development of models that explain the complex interactions of light and matter are considered. The detailed studies provide examples of innovative technologies used for research and communication.

Students continue to undertake extensive and regular experimental work in the laboratory. They design and carry out investigations, collect accurate data, evaluate the quality of data and measurement processes and make conclusions based on the data.

Mathematical modelling, including calculations, continues to be used to organise first-hand and second-hand data, to link concepts, to make predictions and to identify trends. Students analyse and solve more complex qualitative and quantitative problems.

Computer and/or graphical calculator programs are used to collect and analyse first-hand and second-hand data, and to present investigation findings.

In this unit, students develop conceptual understanding by investigating practical activities and demonstrations. Students record raw qualitative and quantitative data and present processed data, including correct use of units, symbols and formulas, accurately and to ensure that relationships between variables are evident. They select and use appropriate materials, apparatus and measurement procedures to ensure a high degree of reliability and accuracy in the data. Students analyse their results to draw relevant conclusions. They identify sources of error and uncertainties to determine the reliability of data and derived quantities. Alternative interpretation of data and results are identified and explained. They identify and apply safe and responsible practices when completing independent and collaborative investigations.

As a guide between 3½ and 5 hours of class time should be devoted to student practical work for each prescribed area of study and between 3½ and 5 hours of class time should be devoted to student practical work for the detailed study if undertaken in Unit 4.

AREA OF STUDY 1

Electric power

The generation, transmission, distribution and use of electric power are crucial to modern life. Students will use evidence and models of electrical, magnetic and electromagnetic effects in the contexts of electric motors, generators, alternators and transformers, and electric power transmission and distribution. For further information about safety, see ‘Safety’ on page 9.

Outcome 1

On completion of this unit the student should be able to investigate and explain the operation of electric motors, generators and alternators, and the generation, transmission, distribution and use of electric power.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- 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
- calculate magnitudes, including determining the directions of, and magnetic forces on, current carrying wires, using $F = nI\ell B$ where the directions of I and B are either perpendicular or parallel to each other
- investigate and explain 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
  - two magnets providing a uniform magnetic field
  - a commutator
  - a DC power supply
- apply a field model to define magnetic flux Φ, using $\Phi = BA$ when the magnetic field is perpendicular to the area, and the qualitative effect of differing angles between the area and the field
- investigate and analyse the generation of emf, including AC voltage and calculations using induced emf, $\varepsilon = -n\Delta\Phi/\Delta t$, in terms of:
  - the rate of change of magnetic flux (Faraday’s Law)
  - the direction of the induced current (Lenz’s Law)
  - number of loops through which the flux passes
- explain the production of DC voltage in DC generators and AC voltage in alternators, including the use of commutators and slip rings respectively
- compare DC motors, DC generators and AC alternators
- investigate and 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 ($V_{p\text{-}p}$) and peak-to-peak current ($I_{p\text{-}p}$)
- identify rms voltage as an AC voltage which produces the same power in a resistive component as a DC voltage of the same magnitude
- convert between rms, peak and peak-to-peak values of voltage and current
- analyse transformer action, modelled in terms of electromagnetic induction for an ideal transformer, $N_1/ N_2 = V_1/ V_2 = I_2 /I_1$
- analyse the supply of power as $P = VI$ and transmission losses using potential difference across transmission lines ($V = IR$) and power loss ($P = I^2R$)

- explain the use of transformers in an electricity distribution system
- identify and apply safe and responsible practices when working with electricity and electrical measurement.

AREA OF STUDY 2

Interactions of light and matter

Light has been described both as a particle and as a wave. The electron has wave-like properties too. This has led to different ways of thinking, not only about light, but also about matter. These ideas are explored using experimental evidence and conceptual models so that the development of the ideas can be followed alongside developments in technology.

Students will use models and explanations to interpret evidence about the interactions of light and matter.

Outcome 2

On completion of this unit the student should be able to use wave and photon models to analyse, interpret and explain interactions of light and matter and the quantised energy levels of atoms.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- 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, $pd = n\lambda$, $pd = (n - \frac{1}{2})\lambda$ respectively
  - qualitative effect of wavelength, distance of screen and slit separation on interference patterns
- explain the effects of varying the width of gap or diameter of an obstacle on the diffraction pattern produced by light of appropriate wavelength in terms of the ratio λ/w (qualitative)
- 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, $E_{k_{max}} = hf - W$, using energy units of joule and electron-volt
  - effects of intensity of incident irradiation on the emission of photoelectrons
- describe why the wave model of light cannot account for the experimental photoelectric effect results
- 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, $\lambda = h/p$
- compare the momentum of photons and of matter of the same wavelength including calculations using $p = h/\lambda$
- explain the production of atomic absorption and emission spectra, including those from metal vapour lamps
- interpret spectra and calculate the energy of photons absorbed or emitted, $\Delta E = hf$

- analyse the absorption of photons by atoms, not including their bombardment by electrons, in terms of:
  - the change in energy levels of the atom due to electrons changing state
  - the frequency and wavelength of emitted photons, $E = hf = hc/\lambda$
- describe the quantised states of the atom in terms of electrons forming standing waves, recognising this as evidence of the dual nature of matter
- identify and apply safe and responsible practices when working with light sources, lasers and related equipment.

AREA OF STUDY 3

Detailed studies

One detailed study is to be chosen from six detailed studies in either Unit 3 or Unit 4. The detailed study is to be selected from:

- Einstein's special relativity
- Materials and their use in structures
- Further electronics
- Synchrotron and its applications
- Photonics
- Sound.

The selected detailed study requires approximately 12 hours of class time.

Detailed study 3.1: Einstein's special relativity

When observers are moving at speeds approaching the speed of light, the Newtonian mechanics must be modified to include a more general understanding of the relation between time and space. This is Einstein's theory of special relativity. Electrons in cathode ray tubes and particle accelerators travel at speeds where it is necessary to use relativistic corrections.

Outcome 3.1

On completion of this unit the student should be able to use Einstein's theory of relativity to describe and explain relativistic motion and effects, and make comparisons with classical descriptions of motion.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- describe the prediction from Maxwell's equations that the speed of light depends only on the electrical and magnetic properties of the medium through which it is passing, and not on the speed of the source or the speed of the medium
- compare the prediction from Maxwell's equations of an absolute speed of light with the classical principle of relativity, that is, no absolute zero for velocity; all velocity measurements are relative to the frame of reference
- 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 conclusions drawn from the Michelson–Morley experiment in terms of Einstein's second postulate
- apply simple thought experiments to show that:
  - the time interval between two events differs depending on the motion of an observer relative to the events
  - length contraction of an object occurs in the direction of its motion when observed from a different frame of reference
- explain the concepts of proper time (t_o) and proper length (L_o) as quantities that are measured in the frame of reference in which objects are at rest
- explain the unfamiliar nature of motion at speeds approaching c by mathematically modelling time dilation and length contraction using the equations $t = t_o\gamma$ and $L = L_o/\gamma$ where $\gamma = (1 - v^2/c^2)^{-1/2}$
- apply Einstein's prediction by showing that the total 'mass-energy' of an object is given by $E_{tot} = E_k + E_{rest} = mc^2$ where $m = m_o\gamma$ and so kinetic energy, $E_k = (\gamma - 1)m_oc^2$
- explain that mass can be converted into energy and vice versa, $E = \Delta mc^2$.

Detailed study 3.2: Materials and their use in structures

The external force applied to a material can result in changes to the shape of the material. The type of force acting upon the material, the shape of the material and how the material is used can influence the behaviour of a structure. The work done in changing the shape of a material can result in energy being stored in the material under strain (strain energy), or it can result in the destruction of the material. This study looks at the behaviour of materials under load and how this behaviour will affect such situations as the stability of a building or the strength of a bridge.

This study aims to develop students' practical skills to enable them to better understand the structures of the natural world and the restrictions of design in the technological world. Students will gain knowledge of the forces acting upon a material, and learn to interpret the data resulting from the changes to the material. They will monitor the energy stored then released, and be able to make comparisons of material properties. Investigations of the shape and composition of the material will be carried out to determine its behaviour under stress up to the point of its destruction.

Students will use properties of structures and materials in the context of construction and design.

Outcome 3.2

On completion of this unit the student should be able to analyse and explain the properties of construction materials, and evaluate the effects of forces and loads on structures and materials.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- identify different types of external forces such as compression, tension and shear, that can act on a body, including gravitational forces
- evaluate the suitability of different materials for use in structures, including beams, columns and arches, by comparing tensile and compressive strength and stiffness or flexibility under load
- analyse the behaviour of materials under load in terms of extension and compression, including Young's modulus, $Y = \sigma/\varepsilon$
- calculate the stress and strain resulting from the application of compressive and tensile forces and loads to materials in structures, $\sigma = F/A$, $\varepsilon = \frac{\varnothing\ell}{\ell}$
- describe brittle and ductile failure and apply data to predict brittle or ductile failure under load

- calculate the potential energy stored in a material under load (strain energy) using area under stress versus strain graph
- evaluate the toughness, as measured by the total area under the stress-strain graph, of a material tested to the point of failure
- describe elastic or plastic behaviour of materials under load and the resulting energy transformed to heat
- evaluate the suitability of a composite material for its use in a structure by considering its properties and the properties of the component materials (maximum of three components)
- calculate torque, $\tau = r \perp F$
- analyse translational forces and torques in simple structures, including uniform columns, struts, ties, beams, cables and simple two-dimensional trusses
- identify and apply safe and responsible practices when working with structures, materials and associated measuring equipment in investigations of materials.

Detailed study 3.3: Further electronics

An understanding of electronic systems may be approached through the study of the functions of the basic building blocks of such systems, both separately and combined.

The construction project to be used for the development of understanding of component principles and demonstration of practical skills is a low voltage AC to DC voltage regulated power supply system. Knowledge and understanding of the role of the transformer in the power supply system is required. Knowledge and understanding of the internal working of the transformer is not required.

The project will require the connection of components into a functional electronic system, as well as the use of appropriate test and measuring equipment.

Students will use electronic devices, circuits, test and measuring equipment in the context of the design and evaluation of a low voltage AC to DC smoothed voltage regulated power supply system. For further information about safety, see ‘Safety’ on page 9.

Outcome 3.3

On completion of this unit the student should be able to design and investigate an AC to DC voltage regulated power supply system, and describe and explain the operation of the system and its components, and the effects of test equipment on the system.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- design and investigate an AC to DC smoothed voltage regulated power supply system, given a range of AC input voltages (specified as root mean square, peak, and peak-to-peak), smoothing conditions and resistive loads
- describe the role of a transformer, including the analysis of voltage ratio, $N_1/N_2 = V_1/V_2$, but not including induction
- describe effects on the DC power supply system of changes to the components used
- interpret information from the display of an oscilloscope in terms of voltage as a function of time
- analyse circuits, including fault diagnosis, following selection and use of appropriate measuring devices, including analogue meters, multimeters, and an oscilloscope
- evaluate the operation of a circuit in terms of its design brief by selecting measurements of potential difference (voltage drop) and current (using analogue meters, multimeters and an oscilloscope) in the DC power supply circuit

- explain the function of diodes in half-wave and full-wave bridge rectification
- explain the effect of capacitors in terms of:
  - potential difference (voltage drop) and current when charging and discharging
  - time constant for charging and discharging, $\tau = RC$
  - smoothing for DC power supplies
- apply the current–voltage characteristics of voltage regulators, including Zener diodes and integrated circuits, to circuit design
- describe, qualitatively, the effect on the magnitude of the ripple voltage of changing the effective load, the capacitance and the input supply voltage (magnitude and period)
- describe the use of heat sinks in electronic circuits
- calculate power dissipation in circuit elements, $P = VI$, $P = I^2R$, $P = V^2/R$
- identify and apply safe and responsible practices when undertaking investigations involving electrical and electronic equipment.

Detailed study 3.4: Synchrotron and its applications

This detailed study applies and extends physics ideas from electromagnetism and the quantum interactions of light and matter. The basic physics concepts underlying the operation and use of The Australian Synchrotron are explored.

The operation of a synchrotron as a large ring accelerator of charged particles can be understood through the physics of the movement of electrons in electric fields and magnetic fields, and the production of electromagnetic radiation by accelerated electrons. The synchrotron as an advanced light source can be understood through the application of ideas about the interaction of light and matter.

The use of synchrotron radiation to investigate the structure and chemical bonding of particular materials provides examples of important applications of this technology qualitatively, and simple two-dimensional diffraction patterns. These can be investigated using supplied data.

Although it is understood that electrons moving in a synchrotron travel at speeds that involve relativistic effects, for the purposes of this study these effects will not be considered.

Students will apply their understanding about synchrotron radiation in the context of investigating materials.

Outcome 3.4

On completion of this unit the student should be able to describe the basic design and operation of The Australian Synchrotron and the production, characteristics and interactions with targets of synchrotron radiation.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- describe that an oscillating electron produces electromagnetic radiation, and similarly, that electromagnetic radiation is produced when the direction of motion of an electron changes since the changing electric field produces a changing magnetic field
- analyse acceleration of electrons in a synchrotron in terms of:
  - applying a force in the direction of motion of the electron (due to an electric field, $F = qE$)
  - applying a force perpendicular to the direction of motion of the electron (due to a magnetic field, $F = qvB$)

- describe the production of synchrotron radiation by an electron radiating energy at a tangent to its circular path
- analyse the acceleration of electrons in an electron gun, $F = qV/d$ and $\Delta E_k = qV$
- analyse 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
- calculate the radius of the path followed by a low-velocity electron in a magnetic field, $qvB = mv^2/r$
- describe the basic design of The Australian Synchrotron including the general purpose of the electron linac (details about drift tubes and RF cavities are not required), circular booster, storage ring and beamlines
- compare the characteristics of synchrotron radiation, including brightness, spectrum and divergence with the characteristics of electromagnetic radiation from other sources including lasers and X-ray tubes
- 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
- describe the production of light by insertion devices (dipoles, wigglers and undulators) and the properties of the light produced in terms of relative brightness and energy
- describe the operation of a typical beamline as a path that radiation travels that allows the radiation to be tuned and that directs the radiation to a target
- analyse data from experiments that involve the interactions of synchrotron radiation with a sample, including:
  - X-ray (Bragg) diffraction, Bragg's Law $n\lambda = 2d\sin\theta$ used to determine the atom spacing in crystalline structures
  - the production of X-ray absorption spectra and the interpretation of these spectra to calculate the energy of photons absorbed, $\Delta E = hf$
- identify and describe, using data, types of X-ray scattering, including elastic (Thomson) scattering and inelastic (Compton) scattering, excluding calculation of conservation of momentum in two dimensions or angular momentum or energy and momentum dependence.

Detailed study 3.5: Photonics

Photonics is the science of using light energy to collect and manipulate information. Photonics is involved with all facets of visible, ultraviolet and infrared radiation, including its production, detection, propagation and manipulation. The general principles of photonics apply across the entire electromagnetic spectrum, including radiowaves, microwaves, infrared, visible light and X-rays.

Photonics spans a vast array of optical phenomena where light is sometimes modelled as a stream of particles each with a discrete quantum of energy (photons) and sometimes as a continuous wave. Earlier ideas related to electronics, photonics and light are extended into an investigation of how photonics impacts on technological developments in our society.

Students will use evidence and models about light and its use in photonic devices in the contexts of domestic, scientific and industrial applications.

Outcome 3.5

On completion of this unit the student should be able to apply the photon and wave models of light to describe and explain the operation of different light sources and fibre optic wave-guides, and analyse their domestic, scientific and industrial uses.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- describe the production of incoherent light from wide spectrum light sources, including the Sun, light bulbs, and candles, in terms of the random thermal motion of valence electrons when atoms collide
- explain light emission from light emitting diodes (LEDs) as the energy emitted when electrons move from the conduction band of a semiconductor to the valence band (excluding n and p type materials)
- analyse the effect of band gap energy on LED colour, $E_g = hf = hc/\lambda$
- describe the production of light by coherent light sources (lasers), in terms of light amplification via stimulation from external photons
- describe laser light in terms of coherence, wavelength and phase
- analyse the operation of fibre optic wave-guides in terms of:
  – light gathering ability using Snell's Law, critical angle, total internal reflection and acceptance angle
  – attenuation by Rayleigh scattering
  – attenuation due to absorption by impurities in the fibre as well as the molecules that make up the fibre
  – physical characteristics of single mode and multimode optical fibres (step and graded index)
  – causes of and methods to minimise material dispersion and modal dispersion
- compare optical fibres that are used for short and long distance telecommunications
- explain fibre optic imaging in terms of coherent and incoherent bundles and in terms of composing images using many fibres, and that these fibres represent the pixels that form the image
- describe the operation of optical fibres as simple, intensity-based sensors
- identify and apply safe and responsible practices when working with photonics equipment.

Detailed study 3.6: Sound

This detailed study extends student understanding of waves together with aspects of electromagnetism to the recording and reproducing of sound. Ideas of sound and electromagnetism combine to aid understanding of the operation and use of microphones and speakers, control of sound level, need for hearing protection and acoustic properties of recording and performance spaces.

Students will use evidence and models of sound and electromagnetism in the contexts of music, and speaking and hearing.

Outcome 3.6

On completion of this unit the student should be able to apply a wave model of sound and a field model of electromagnetism to describe, analyse and evaluate the recording and reproduction of sound.

To achieve this outcome the student will draw on the following key knowledge and apply the key skills listed on page 12.

Key knowledge

- 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 (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
- explain resonance in terms of the superposition of a travelling wave and its reflection
- analyse, for strings and open and closed resonant tubes, the fundamental as the first harmonic, and subsequent harmonics

- describe in terms of electrical and electromagnetic effects, the operation of
  - microphones, including electret-condenser, crystal, dynamic and velocity microphones
  - dynamic loudspeakers
- describe the effects of baffles and enclosures for loudspeakers in terms of the interference of sound waves due to phase difference
- interpret frequency response curves of microphones, speakers, simple sound systems and hearing, including loudness (phon)
- evaluate the fidelity of microphones and loudspeakers in terms of:
  - the intended purpose of the device
  - the frequency response of the system
  - physical construction (qualitative)
- describe diffraction as the directional spread of various frequencies in terms of different gap width or obstacle size, including the significance of the magnitude of the λ/w ratio
- identify and apply safe and responsible practices when working with sound sources and sound equipment.

ASSESSMENT

The award of satisfactory completion for a unit is based on a decision that the student has demonstrated achievement of the set of outcomes specified for the unit. This decision will be based on the teacher's assessment of the student's overall performance on assessment tasks designated for the unit. The Victorian Curriculum and Assessment Authority publishes an assessment handbook that includes advice on the assessment tasks and performance descriptors for assessment.

The key knowledge listed for each outcome and application of key skills should be used as a guide to course design and the development of learning activities. The key knowledge and application of key skills do not constitute a checklist and such an approach is not necessary or desirable for determining the achievement of outcomes. The elements of key knowledge and application of key skills should not be assessed separately.

Assessment of levels of achievement

The student's level of achievement for Unit 4 will be determined by School-assessed Coursework and an end-of-year examination.

Contribution to final assessment

School-assessed Coursework for Unit 4, including the detailed study, will contribute 24 per cent to the study score.

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.

School-assessed Coursework

Teachers will provide to the Victorian Curriculum and Assessment Authority a score representing an assessment of the student's level of achievement.

The score must be based on the teacher's rating of performance of each student on the tasks set out in the following table and in accordance with the assessment handbook published by the Victorian Curriculum and Assessment Authority. The assessment handbook also includes advice on the assessment tasks and performance descriptors for assessment.

Assessment 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 optional assessment tasks are used, teachers must ensure that they are comparable in scope and demand. Teachers should select a variety of assessment tasks for their program to reflect the key knowledge and application of key skills being assessed and to provide for different learning styles.

Outcomes	Marks allocated*	Assessment tasks
Outcome 1 Investigate and explain the operation of electric motors, generators and alternators, and the generation, transmission, distribution and use of electric power.	40	At least three different tasks selected from the following:** • a student-designed extended practical investigation • a summary report of selected practical activities from the student's log book • a multimedia presentation • a data analysis • a report (written, oral, annotated visual) • a test (short answer and extended response) • a response to a media article. **Across the assessment tasks selected in Unit 3 and 4, at least one of the assessment tasks must be an extended practical investigation and at least one of the assessment tasks must be a summary report of selected practical activities.
Outcome 2 Use wave and photon models to analyse, interpret and explain interactions of light and matter and the quantised energy levels of atoms.	30	
Detailed study **Outcome 3.1** Use Einstein's theory of relativity to describe and explain relativistic motion and effects, and make comparisons with classical descriptions of motion. **Or** **Outcome 3.2** Analyse and explain the properties of construction materials, and evaluate the effects of forces and loads on structures and materials. **Or** **Outcome 3.3** Design and investigate an AC to DC voltage regulated power supply system, and describe and explain the operation of the system and its components, and the effects of test equipment on the system. **Or** **Outcome 3.4** Describe the basic design and operation of The Australian Synchrotron and the production, characteristics and interactions with targets of synchrotron radiation. **Or** **Outcome 3.5** Apply the photon and wave models of light to describe and explain the operation of different light sources and fibre optic wave-guides, and analyse their domestic, scientific and industrial uses. **Or** **Outcome 3.6** Apply a wave model of sound and a field model of electromagnetism to describe, analyse and evaluate the recording and reproduction of sound.	30	
Total marks	**100**	

*School-assessed Coursework for Unit 4 contributes 24 per cent to the study score.

End-of-year examination

Description

The examination will be set by a panel appointed by the Victorian Curriculum and Assessment Authority. All outcomes in Unit 3, and Outcomes 1 and 2 in Unit 4 are examinable. The student's selected Detailed Study in Outcome 3 Unit 4 will also be examined. All key knowledge that underpins the outcomes in Units 3 and 4 and the set of key skills listed on page 12 are examinable.

Conditions

The examination will be completed under the following conditions:

- Duration: two and a half hours.
- Date: end-of-year, on a date to be published annually by the Victorian Curriculum and Assessment Authority.
- Victorian Curriculum and Assessment Authority 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 Victorian Curriculum and Assessment Authority.

Contribution to final assessment

The examination will contribute 60 per cent to the study score.

Further advice

The Victorian Curriculum and Assessment Authority publishes specifications for all VCE examinations on the Victorian Curriculum and Assessment Authority 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.

Advice for teachers

DEVELOPING A COURSE

A course outlines the nature and sequence of teaching and learning necessary for students to demonstrate achievement of the set of outcomes for a unit. The areas of study broadly describe the learning context and the knowledge required for the demonstration of each outcome. Outcomes are introduced by summary statements and are followed by the key knowledge which relate to the outcomes.

Teachers must develop courses that include appropriate learning activities to enable students to develop the knowledge and application of key skills identified in the outcome statements in each unit. Teachers should design courses that develop conceptual understanding of physics ideas and apply the key skills identified on page 12. Being aware of student alternative conceptions can assist teachers to develop activities that encourage students to revisit ideas and move towards developing a more scientifically accepted conception.

Detailed studies

For Units 1 and 2 a selection of six detailed studies is provided. One detailed study is to be selected for study in Unit 1 and a second, different, detailed study is to be selected for study in Unit 2. Teachers are advised to select a detailed study which builds on material covered in the areas of study undertaken in that unit. Teachers may select a particular detailed study of the six available detailed studies that all students in the class will study, or they may offer a selected number of the six available detailed studies from which students make a selection. Where alternative assessment tasks are used to assess different detailed studies, teachers must ensure that they are comparable in scope and demand.

The table below offers possible pairings of detailed studies with Areas of Study 1 and 2 in each unit.

Unit	Area of study	Possible detailed studies
1	Nuclear physics and radioactivity	Energy from the nucleus Medical physics
1	Electricity	Investigations: Sustainable energy sources
2	Motion	Astronomy Astrophysics Investigations: Flight Investigations: Sustainable energy sources
2	Wave-like properties of light	Astronomy Astrophysics Medical physics

For Units 3 and 4 a selection of six detailed studies is provided. One detailed study is to be selected for study at any time during Unit 3 or Unit 4. Reporting of the outcome for the selected detailed study for each student will be recorded as part of Unit 4. Teachers may select a particular detailed study of the six available detailed studies that all students in the class will study, or they may offer a selected number of the six available detailed studies from which students make a selection. Where alternative assessment tasks are used to assess different detailed studies, teachers must ensure that they are comparable in scope and demand. Assessment of the detailed study will be through both School-assessed Coursework and an end-of-year examination.

Units 1 and 2 assessment

For Units 1 and 2, teachers must select assessment tasks from the list provided in the study design. A variety of tasks should be provided and the mix of tasks should reflect the fact that different types of tasks suit different knowledge and skills and different learning styles. Tasks do not have to be lengthy in order to demonstrate the achievement of an outcome.

Units 3 and 4 assessment

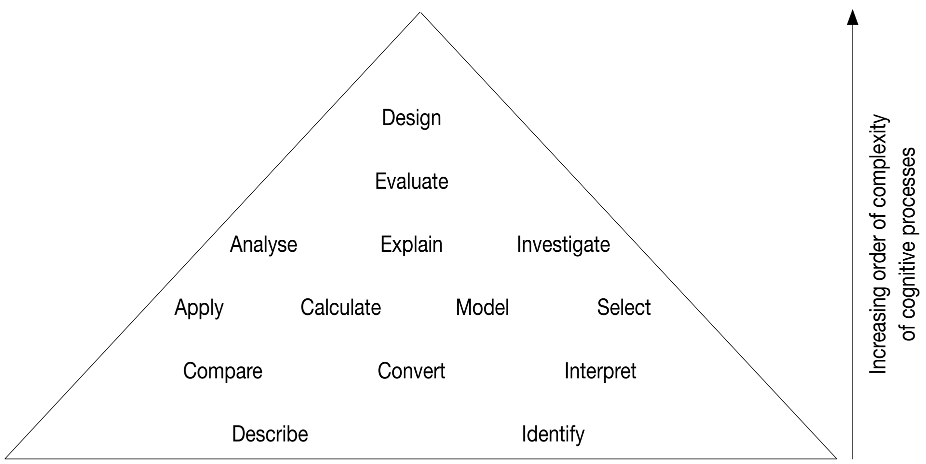
In Units 3 and 4, assessment is more structured. For some outcomes, or aspects of an outcome, the assessment tasks are prescribed. The contribution that each outcome makes to the total score for School-assessed Coursework is also stipulated.

Teachers must ensure that across the assessment tasks selected in Units 3 and 4, at least one of the assessment tasks must be a student-designed extended practical investigation and at least one of the assessment tasks must be a summary report of selected practical activities.

USE OF VERBS IN THE STUDY DESIGN

The points listed in the key knowledge for each area of study and detailed study and the application of key skills listed on page 12 are activated by one of fourteen verbs.

The following 'cognitive triangle' shows the hierarchical nature of the cognitive processes associated with the use of these verbs within the study design. Definitions of these verbs are provided in the following table.



Note: higher order cognitive processes in the above cognitive triangle include capacities of those cognitive processes which appear below them

Verb	Definition	Typical learning examples
Analyse	Use qualitative and quantitative methods to identify and distinguish between the elements and constituent parts of the whole, and explain the relationships between them; recognise patterns.	Consider presented information and clarify concepts and knowledge; use qualitative and quantitative methods to distinguish between components (words, tables, labelled diagrams, calculations, graphs); recognise patterns; identify and relate implications; undertake a graphical analysis of data.
Apply	Use knowledge, ideas, formulas, principles, theories, laws, models and/or techniques in a new situation or context; propose a solution or response to a problem or issue.	Propose a solution or response to a problem or issue; show steps; use algebraic and/or graphical methods as appropriate and according to established rules.
Calculate	Use mathematical formulas and modelling to solve quantitative problems.	Solve numerical problems by using formulas and mathematical processes; find the numerical value of an unknown variable or constant.
Compare	Identify and list the similarities and differences between two or more objects, situations, concepts or processes.	List, tabulate or use a graphic organiser to identify similarities and differences.
Convert	Express quantities in alternative units of measure.	Change a unit of measure of a specific quantity to another unit of measure.
Describe	Communicate the characteristics and features of an event, object, procedure, concept or process using written, oral or visual representations.	Use written, oral or visual representations to communicate characteristics or features.
Design	Create a plan, object, model, system, simulation or set of procedures to suit a particular purpose.	Combine knowledge, skills, materials and processes to develop a solution to a problem.
Evaluate	Make reasoned judgments or decisions on given or collected information, based on established criteria.	Assess the merit (strengths and limitations) of ideas, processes or procedures and reach a conclusion; validate evidence; choose from options based on reasoned arguments.
Explain	Make clear; account for the reason for something or the relationship between cause and effect; state why and/or how.	Provide reasons, mechanisms and outcomes, incorporate quantitative data as appropriate.
Identify	Recognise and name particular elements of a whole or part; select from a number of possibilities; select relevant information or aspects of key ideas.	Recognise and name/label a specific object, element, component or underlying principle or concept; label/annotate components of a system, model or diagram.
Interpret	Construct conceptual meaning from information provided in a variety of forms.	Derive meaning from information presented in multi-modal texts (for example, written, aural and diagrammatic), tables, images and graphical formats.
Investigate	Undertake practical experiments and research to find out the answer to a question or problem.	Conduct experiments and research to find out the answer to a question or problem.

Verb	Definition	Typical learning examples
Model	Use a familiar and known concept or construct to facilitate the understanding of a new and more complex concept or construct.	Show the structure or operation of an object, concept, system or process by using a description, pattern, plan or two- or three-dimensional representation.
Select	Choose from a number of components, options or processes.	Decide which electronic components should be used to construct a circuit for a specific function.

USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY

In designing courses and developing learning activities for Physics, teachers should make use of applications of information and communications technology (ICT) for teaching and learning purposes.

In Physics, information and communications technology can assist students to:

- capture and record data in situations beyond the ability of the human senses
- organise data and identify relationships
- simulate situations which are too dangerous, expensive or inaccessible (remote)
- allow for analysis away from the site of the data creation
- use Internet facilities such as email, forums, websites, blogs, for research and learning purposes
- present understandings, share ideas and data
- develop understandings by visualising thinking.

When planning relevant learning activities, care should be taken to prevent ICT from becoming the focus of the learning activity in place of the specific Physics content and skills focus. Skills of experimentation and content focus should be made explicit. The analysis of data collected should assist to establish an understanding of a physical relationship or to demonstrate a theoretical connection and provide quantitative analysis.

First-hand data collection has been greatly enhanced by developments in the processing capacities of technology. Affordable laboratory-based and portable devices allow for a wide range of data gathering methods. Datalogging using graphical calculators and computer software allow more realistic situations to be investigated productively, both in conventional experiments and student-designed investigations. They add to the power and immediacy of learning activities that can be undertaken in the classroom.

Spreadsheets should be routinely used to investigate relationships between variables and patterns in experimentally obtained data, and to simulate experimental situations, where experiments are not possible or the equipment is not available. Data for spreadsheets can be acquired (or captured) from video analysis, datalogging devices or from pre-recorded sources from the Internet or CD-ROMs. Limitations of the methods of measurement or the graphing model can then be visually portrayed.

Capturing of moving images and analysis for motion studies may be achieved by the use of relatively low-cost computer hardware and software, and peripherals such as digital cameras, although more expensive solutions are commercially available. Second-hand data is readily available from the web at no cost, though first-hand collection is preferable. The analysis of moving images can be achieved manually by playing frame by frame and projecting the images through a data projector. If using an interactive whiteboard, annotations can be made directly onto the whiteboard.

While the main emphasis throughout this study is on the process of gathering data, measuring and analysis, there is also some importance placed on the presentation and communication of findings. The study concentrates on the mechanisms and understandings of major physics concepts; however, encouraging students to communicate the specific details in a variety of ways enables processing and organising information which enhances the learning process. This also takes account of different learning styles, and by demonstrating their knowledge in a presentation, the whole class gains the benefit of the individual's learning.

EMPLOYABILITY SKILLS

The VCE Physics study provides students with the opportunity to engage in a range of learning activities. In addition to demonstrating their understanding and mastery of the content and skills specific to the study, students may also develop employability skills through their learning activities.

The nationally agreed employability skills* are: Communication; Planning and organising; Teamwork; Problem solving; Self-management; Initiative and enterprise; Technology; and Learning.

Each employability skill contains a number of facets that have a broad coverage of all employment contexts and can describe all employees. The table below links those facets that may be understood and applied in a school or non-employment related setting, to the types of assessment commonly undertaken within the VCE study.

Assessment task	Employability skills
Annotated folio of activities	**Communication** (writing to the needs of the audience) **Planning and organising** (collecting, analysing and organising information) **Technology** (using information technology to organise data)
Data analysis	**Communication** (reading independently; writing to the needs of the audience; using numeracy) **Planning and organising** (collecting, analysing and organising information) **Problem solving** (using mathematics to solve problems; testing assumptions taking the context of data and circumstances into account) **Technology** (using information technology to organise data)
Media response	**Communication** (listening and understanding; reading independently; writing to the needs of the audience; persuading effectively) **Problem solving** (testing assumptions taking the context of data and circumstances into account)
Multimedia presentation	**Communication** (sharing information; speaking clearly and directly) **Learning** (being open to new ideas and techniques) **Technology** (having a range of basic information technology skills; using information technology to organise data; being willing to learn new information technology skills)

*The employability skills are derived from the Employability Skills Framework (*Employability Skills for the Future*, 2002), developed by the Australian Chamber of Commerce and Industry and the Business Council of Australia, and published by the Commonwealth Department of Education, Science and Training.

Assessment task	Employability skills
Report (oral/written/visual)	**Communication** (sharing information; speaking clearly and directly; writing to the needs of the audience; using numeracy) **Learning** (being open to new ideas and techniques) **Planning and organising** (collecting, analysing and organising information) **Technology** (using information technology to organise data)
Student-designed investigation	**Communication** (reading independently; writing to the needs of the audience; using numeracy) **Initiative and enterprise** (generating a range of options; initiating innovative solutions; being creative) **Learning** (being open to new ideas and techniques) **Planning and organising** (planning the use of resources including time management; collecting, analysing and organising information; weighing up risk, evaluating alternatives and applying evaluation criteria) **Problem solving** (developing practical solutions; testing assumptions taking the context of data and circumstances into account) **Self-management** (evaluating and monitoring own performance) **Teamwork** (working as an individual and as a member of a team; knowing how to define a role as part of the team) **Technology** (using information technology to organise data)
Summary report of activities	**Communication** (writing to the needs of the audience) **Planning and organising** (collecting, analysing and organising information)
Test	**Communication** (writing to the needs of the audience) **Problem solving** (using mathematics to solve problems)

LEARNING ACTIVITIES

Examples of learning activities for each unit are provided in the following sections. Shaded learning activities are explained in detail in accompanying shaded boxes.

Unit 1

AREA OF STUDY 1: Nuclear physics and radioactivity

Outcome 1	Examples of learning activities
Explain and model relevant physics ideas to describe the sources and uses of nuclear reactions and radioactivity and their effects on living things, the environment and in industry.	using the Internet, research the sequence of events at Chernobyl in 1986; What were some of the predictions for consequences of exposure at that time? What has happened since then? use a radiation monitor to observe activity of a variety of sources; explain how a smoke detector works; What arrangements should be made for the disposal of a smoke detector? use a 'determine your radioactive exposure' worksheet from the Australian Nuclear Science and Technology Organisation kit use a radiation counter to record the decay of the short-lived protactinium source and determine its half-life how are X-ray images formed? Why do dentists 'stand away' when teeth X-rays are being made? What are the benefits/dangers of having teeth X-rayed? using a container of dice, calculate through a series of tips and removals the 'half life' of dice; research this concept

Detailed example

RADIOACTIVE DECAY SIMULATION

Place 50 dice (or 50 small wooden cubes with one face marked) in a suitable container. Shake and tip the contents of the container into a corner of the room. Pick up the dice that have the '6' face or the marked face uppermost and put them aside. Record the number removed. Return the others to the container and repeat the process until there are none left in the container.

Make a tally table showing the number of items left after each tip. Plot this number against tip number.

How many tips did it take for all items to be removed? Aggregate the class data. What was the total number of items initially? How many remained after the first tip? Graph the aggregated data and draw a smooth curve to determine the half life of dice.

Research this phenomena called the 'half life' of the sample population.

AREA OF STUDY 2: Electricity

Outcome 2

Investigate and apply a basic DC circuit model to simple battery operated devices, car and household (AC) electrical systems, and describe the safe and effective use of electricity by individuals and the community.

Examples of learning activities

explore conceptual understandings and alternative prior conceptions of electricity using techniques such as those described by the conceptual understanding procedures (CUPs), which include the worksheets 'What is current?' and 'What is voltage?'

experiment with a set of batteries and light bulbs in various series and parallel combinations and explain the observations; add ammeters and voltmeters to the batteries and light bulb circuits to measure the currents, voltages and resistances of the bulbs

read an article on 'electric shock' and make notes on what happens when somebody receives a shock

make a table of typical power usage of domestic appliances and investigate domestic electrical safety provisions

use a simulation program to model the operation of a DC circuit

set experiments with an opportunity for extension or modification by the student, e.g. investigating variation of current with applied voltage for a resistor to combinations of resistors and non-ohmic devices

dismantle old electrical appliances (from which all cords and plugs have been removed) and explain the workings

Detailed example

INVESTIGATION OF ELECTRICAL APPLIANCES

A range of old domestic electrical appliances can easily be obtained by an appeal to the school community. Items such as toasters, hair dryers, irons and heaters are suitable. For safety reasons it is important to remove any cords and plugs.

The appliances can be prepared so that it is not too difficult for the students to dismantle them. The students draw a circuit diagram of the wiring in the appliance. Help, where necessary, to identify components such as thermostats and safety cut-outs which may not be obvious to them.

Switches will often be found which combine elements in different series and parallel combinations to alter the power settings.

In the case of heating elements the resistance can be determined and from that an estimate of the power used in the appliance made. This can be compared to the rating on the appliance. Where electric motors are involved, the resistance will not give a good indication. The reasons for this can be discussed with students.

Ensure that any appliances examined are not reassembled for use.

Unit 2

AREA OF STUDY 1: Motion

Outcome 1

Investigate, analyse and mathematically model motion of particles and bodies in terms of Aristotelian, Galilean and Newtonian theories.

Examples of learning activities

explore conceptual understandings and alternative prior conceptions of motion using techniques such as those described by the conceptual understanding procedures (CUPs)

compare the explanation of motion offered by Aristotle and Newton for a ball rolling downhill

discuss Galileo's famous 'thought experiment' in his dialogues in which he shows that Aristotle's argument that an object will fall at a speed according to its weight is logically flawed

observe, measure and record data taken from an excursion to a playground or amusement park; provide detailed graphical analysis of each motion observed, estimating speed, frequency, periodicity, and accelerations

use bathroom scales to measure reaction forces when sitting, leaning against a wall and walking on the scales

use bathroom scales to observe the change in reaction force when riding a lift in a tall building

use a motion detector to describe simple walking movements in terms of distance, speed and acceleration

measure the acceleration of trolleys of different masses under the influence of a range of known forces

discuss the reasons that a falling object usually does not accelerate at the expected rate of 9:8 m s^{-2}

measure students' power output as they run up a flight of stairs

graph force vs extension for a catapult and relate the stored energy to the vertical height to which it will fire a projectile; ensure safe use of the catapult

observe movement through measuring acceleration, video recording, constructing models, and examining energy cycles in athletes

Detailed example

OBSERVATIONS OF MOVEMENT

Use data gathering devices to record an object falling under gravity. Useful comparisons between tickertape and electronic means may be made. Alternatives include: ultrasonic detector, accelerometer, lightgate, two photogates, electronic timer circuit and video analysis.

Use a video recorder to record 5–10 seconds of motion. Either from the video or using alternative measurements gathered by ultrasonic detectors, produce quantitative data and prepare accurate graphs of the movement.

Present the findings in electronic format such as a web page, slideshow, video with a set of questions for the rest of the class to complete as part of their motion coursework, e.g. Second-hand data analysis.

Construct a roller-coaster with a low friction ‘car’. Perform measurements along ‘the run’ to determine the speed and vertical displacement of the ‘car’. Calculate the expected values of kinetic energy at suitable points along ‘the run’.

Contrast, compare and account for the values measured and calculated.

Present the findings in electronic format, with a set of student questions for the rest of the class group to attempt as part of their coursework.

Examine the energy changes as a high jump athlete rises, falls and lands on the protective mat. Provide a complete description, prediction and verification of kinetic and potential energy states through a complete cycle.

Determine the launch and landing speeds from the maximum height. Find the force–extension relationship for the protective mat. Show what happens when the athlete lands vertically or horizontally.

Present the findings as a comparison of kinetic, gravitational potential and potential energy in the mat as well as total energy as a function of position. Account for any changes in total energy.

AREA OF STUDY 2: Wave-like properties of light

Outcome 2

Describe and explain the wave model of light, compare it with the particle model of light and apply it to observed light phenomena in practical investigations.

Examples of learning activities

use slinky springs to observe basic properties of transverse and longitudinal waves

compare wavelength, frequency and speed of commonly observable waves with those of light, considered as a wave phenomenon

experiment with Polaroid sunglasses or film

look at a white line on black, and vice versa, through a prism

use the Internet to investigate the refractive index of a material and its relationship to any other physical parameters

use the Internet to research the refractive indices of different components of the human eye and explore refraction of light as it propagates through the eye

construct a poster (a formal, structured text and graphics explanation) on the operation and uses of an optical instrument

answer questions on an 'Inside Science' from New Scientist magazine article, or similar, on optical fibres

investigate qualitatively the changing nature of the image in a concave mirror and/or a convex lens

experiment with two convex lenses of different focal length to construct a simple telescope

use the Internet to research Brewster's angle, Pepper's Ghost, HUD (Head Up Display); describe each example and explain in optics terms how each operates

use a spreadsheet to explore the mathematical relationship experimentally found between the angle of incidence and the angle of refraction

investigate the wave nature of light, looking at light intensity, the refractive index, scattering, internal reflection and critical angle, interference and diffraction and optical fibres

Detailed example

THE WAVE NATURE OF LIGHT

Wave-like behaviour of light

Observe examples of light reflection, refraction, diffraction including laboratory observation of reflection and refraction of water waves. Describe how and where the behaviour occurs. Compare light phenomena and water waves – and identify that light acts like water waves. Define the terms: wavelength, frequency, period, direction of travel, wave speed.

Intensity of light is dependent on the distance of the observer from the source. Examine evidence for the relationship. Collect your own data and comment on your results.

Use the wave model to show how light intensity changes with the distance from the source. Quantitative analysis can be attempted. A simple approach is to use one and then four light bulbs and a solar cell to show that the output is the same twice as far from the four bulbs. Technology applications allow for precise data to be collected by students in the laboratory.

Determination of refractive index

Different materials behave differently. Measure incident and emerging ray directions and calculate refractive index. Study its application to forensic science to assist with identification of crime scene glass fragments and correlation with suspect's samples.

Scattering

Why is the sky blue? Why is milk white? Why are diesel fumes black? Why are lobsters/crayfish red? Why is the deep sea green? Why is the edge of clear glass green?

Research using the Internet to find answers and provide a simple explanation of how light is scattered, e.g. Rayleigh scattering.

Internal reflection and critical angle

Explore the changes in the ratio of transmission and reflection as the incident angle is increased. Identify conditions for total internal reflection (calculate the critical angle). Observe colour dispersion near the critical angle.

Observing interference and diffraction

Observe the conditions needed for Newton's rings to be observed. Describe Fresnel diffraction and how Poisson's spot was named.

Research using the Internet why Joseph Fraunhofer might view the reflections from a CD in a different light. What is a diffraction grating? Measure the distance between CD tracks by indirect means.

Modelling an optical fibre

Launch a ray into a long rectangular block so that the internal rays totally internally reflect. Identify core (glass) and clad (air). Measure launch and critical angles. Compare with predicted values.

AREA OF STUDY 3.1: Astronomy

Outcome 3.1

Use observations to explain the motions of stars and planets, and describe models of planetary motion.

Examples of learning activities

use an astronomical almanac to plan observations of celestial objects and significant events during the semester; discuss with other class members

keep a Moon diary for four consecutive weeks; note location of Moonrise/set and phase for as many nights as possible; compare with the Internet posted version for your location

observe the Moon while rising (or setting) when near to the horizon; observe again when fully 'in the air'; compare the relative sizes of the Moon; research on the Internet the 'perception of a rising Moon' effect

obtain relevant data from www.heavens-above.com for your time and location

use the Internet to research and observe the ISS, Starshine or an iridium 'flare'; Do the predicted times and locations match those you observed?; estimate the speed of the satellite using the orbit time data; an estimate of the height can be calculated from this data

using data provided on the Internet from observations on retrograde motion of planets, construct an explanation in terms of both the Ptolemaic and the geocentric model for planetary motion; Which explanation is better? Why?

what evidence best supports the heliocentric model? Why?; use planetary data and spreadsheet graphs to support your argument

describe the known solar system before 1973 (pre-Pioneer and Voyager) and the current known solar system

for each time period include details of planet/moons/orbit radius/rotation time (in Earth days)/revolution or orbit time (in Earth years)/description of the surface of the planet

record sketches of telescopic observations of the Moon, planets, planetary moons, stars, binary stars, open and globular star systems and nebulae

investigate the diurnal and annual rotation in different parts of the sky by nightly observations spread over a period of time

Detailed example

INVESTIGATION INTO THE NIGHT SKY

Students discuss with their teacher ways in which they can determine the position of various objects in the night sky. For example, some could construct a simple protractor based quadrant measuring azimuth and altitude, while others may line up objects in their yard. For instance, a vertical post could be used in conjunction with a viewing point in order to determine the time at which particular stars or planets cross the meridian.

Alternatively, a drawing of the sky against features on the horizon could be used. Identify advantages and disadvantages of using altazimuth and equatorial coordinate systems.

Some key features in the sky are then identified, depending on the season. In autumn, stars such as Canopus and Sirius, as well as constellations such as Orion and the Southern Cross are easily found. Students would be encouraged to identify and log the motion of these and as many other stars and constellations as possible.

From this exercise students should be able to develop techniques which will enable them to discover the nightly rotation of the stars about the south celestial pole as well as the four minute change in the position of the celestial sphere from night to night. It should also be possible to track the motion of any planets visible through the stars.

AREA OF STUDY 3.2: Astrophysics

Outcome 3.2

Describe and explain methods used to gather information about stars and other astronomical objects and apply this information to models of the nature and origin of the Universe.

Examples of learning activities

unaided eye observation of the night sky:

use a 'starfinder' (physical or electronic) for identification of stars, constellations and planets in the night sky

investigate the diurnal and annual rotation in different parts of the sky by nightly observations spread over a period of time

investigate the relationship between altitude and azimuth and equatorial co-ordinate systems

photograph and measure the rotation of the celestial sphere in different parts of the sky

construct a simple equatorial device for measuring the positions of the stars and planets

use observations of the stars to find methods of finding time, latitude and longitude

using a telescope, observe and draw the Moon and any planets visible in the sky

study the Moon through a telescope and try to reproduce Galileo's measurement of the heights of the mountains

observe the moons of Jupiter through a telescope and measure their periods observe and photograph nebulae, galaxies and other telescopic objects in the sky

plot and measure the length of the shadow of a vertical stick, hence find true north and the altitude of the Sun during the day

use various practical exercises published by magazines such as *Sky and Telescope*; for example, using spectra to determine the orbital speed of Earth; data from stellar parallax measurements to determine astronomical distances

investigate the problem of the determination of longitude and the various solutions proposed to solve it

construct a sundial and relate its features to Earth's movement on its axis and around the Sun

use one of the many websites providing astronomical exercises based on real telescopic observations

undertake a laboratory experiment from the Contemporary Laboratory Experiences in Astronomy (CLEA) set of projects available from www.gettysburg.edu/academics/physics

Detailed example

INVESTIGATE THE AGE OF THE UNIVERSE

One source of good 'laboratory exercises' in astrophysics is the Contemporary Laboratory Experiences in Astronomy (CLEA) set of projects available from: www.gettysburg.edu/academics/physics (choose CLEA)

These experiments can be downloaded and then used offline in the classroom. For example, one such experiment simulates the use of a telescope to obtain the spectra of galaxies.

The red shift can then be measured by comparison of various spectral lines, and from this the recession velocity can be obtained. The distance of the galaxy is determined by finding the absolute and apparent magnitudes. This data can then be entered into a spreadsheet (or plotted on paper) and the Hubble constant found. From the value of the constant, the age of the Universe can be estimated.

AREA OF STUDY 3.3: Energy from the nucleus

Outcome 3.3	***Examples of learning activities***
Describe and explain typical fission and fusion reactions, energy transfer and transformation phenomena of importance in stars and in the production of nuclear energy, and the benefits and risks of the use of nuclear energy as a power source for society.	distinguish the similarities and differences between fusion and fission reactions; Why is energy released in both reactions? What are the end products in each case? nominate some benefits of using the fission process for transforming energy from nuclei to energy in electrical form use a particle model to show how fission causes a heating effect and how the heating effect is used to generate an electrical effect describe how a fission reactor is controlled and the energy output managed describe the process of fusion and explain the statement: 'we are all only stardust after all' explore the effect on the environment of nuclear accidents by accessing sites such as www.angelfire.com/extreme4/kidofspeed/chapter1.html which explores an account of the impact of a nuclear accident on the environment, in this case Chernobyl, long after the accident took place research using the Internet and other sources the operation of a nuclear reactor

Detailed example

INVESTIGATION INTO NUCLEAR REACTORS

Use the Internet or other resources to find out about the main types of nuclear reactors in use around the world today. How does each type of reactor perform the key tasks of control of the rate of reaction, moderation, and cooling? What are the advantages and disadvantages of each type?

One of the major issues in the operation of a reactor is the prevention of a 'melt down' (as happened in Chernobyl). What is a melt down and why is it such a danger? What sort of precautions can be taken to avoid such problems? What was the reason for the failure of these precautions at Chernobyl? Is there a way to make a nuclear reactor 'fail-safe', and are any such reactors operating?

AREA OF STUDY 3.4: Investigations: Flight

Outcome 3.4

Design, perform and report on an experimental investigation related to an aspect of flight, and explain results and conclusions by including reference to Newton's laws of motion and Bernoulli's principle.

Examples of learning activities

suspend a model aircraft from a spring; balance in the airstream from a fan and investigate the forces

place a light ball in the stream of air from a vacuum cleaner hose and demonstrate the Bernoulli effect

discuss the effect of the various aerofoil surfaces of an aeroplane and their purposes

operate an electrically driven propeller on a varying voltage and measure the thrust–power relationship

discuss the various forces operating on an aircraft in flight and the effect of each of them

use a flight simulator to investigate aircraft flight and the physics involved

Detailed example

INVESTIGATE FLIGHT

Use a flight simulator program to investigate the effects of the various controls of an aircraft. Some examples: find the relationship between angle of attack, as determined from the cockpit instruments, and speed over a range of fixed power settings; investigate the effect of the flap settings on the rate of climb at various power settings; investigate the relationship between power and speed in straight and level flight. Attempt to explain all of these in terms of the physics involved.

Place a model aeroplane or aerofoil in the air flow from a fan. Measure the force required to maintain it in a fixed position. Graph the force vs windspeed.

AREA OF STUDY 3.5: Investigations: Sustainable energy sources

Outcome 3.5

Use concepts of energy transfer and transformations to design, conduct and report on an experimental investigation into an aspect of a renewable energy supply system.

Examples of learning activities

discuss our need for energy and the way it has grown in the modern industrial and technological society; identify different uses for the word ‘energy’

from the Internet or other sources find information to construct a flow chart showing the flow of energy through the Australian society

from the Internet or other sources find information about alternative energy sources such as solar (passive, thermal or photovoltaic), wind, tidal, wave, oceanic thermal currents, geothermal, hot dry rocks

investigate the efficiency of key energy transformations such as from source to kinetic energy or electricity, or from electricity to kinetic energy or to heat

investigate the efficiency of an electric motor in lifting a weight

research the environmental issues that have involved energy production such as the controversy over the Newport power station, the Franklin River in Tasmania or the proposed Bass Strait power link

investigate materials and their heating and cooling rates; model uses of such material and present a report from data collected

Detailed example

INVESTIGATE ENERGY SUPPLY

Investigate the heating and cooling rates of similar masses of different materials. Select an appropriate material and model its use in maintaining a more consistent temperature of a room during day and night.

Collect appropriate temperature and time data and present a report, including explanations of energy transfer and transformation processes in terms of particles and radiation.

AREA OF STUDY 3.6: Medical physics

Outcome 3.6	*Examples of learning activities*
Describe and explain applications of radioisotopes, optical fibres, waves and lasers to medical diagnosis and treatment, and describe the production and/or simple interpretation of images of the human body produced by the processes of CT, ultrasound or X-rays.	radioisotopes are routinely used to diagnose medical conditions of patients: How is this achieved? What are the limitations of this technology? laser treatment of patients is becoming more frequent: Which procedures are suitable for the use of lasers? Which use is the more common, therapeutic or diagnostic? using the Internet, research what MRI was formerly known as: Why did the procedure undergo a name change? In simple terms, how does an MRI operate? describe how an X-ray procedure is different from that of a PET scan; list the advantages and limitations of using each procedure/s obtain an X-ray or ultrasound image; identify the features shown by the image research using the Internet and other sources the use of radioisotopes to diagnose and treat medical conditions

Detailed example

INVESTIGATION INTO RADIOISOTOPES

Use the Internet and other resources to discover some of the ways in which radioisotopes can be used to diagnose medical conditions.

What are the most common isotopes used to diagnose medical conditions? Where and how are they obtained? In what ways are they used? What sort of requirements are there on the lifetime and activity of the isotopes?

What are the requirements for a radioisotope used for medical treatment and how do they differ from those used in diagnosis? What forms of medical problems can be treated by the use of radioisotopes? In what ways can a sufficient radiation dose be delivered to a cancer without endangering the patient?

Unit 3

AREA OF STUDY 1: Motion in one and two dimensions

Outcome 1

Investigate motion and related energy transformations experimentally, and use the Newtonian model in one and two dimensions to analyse motion in the context of transport and related aspects of safety, and motion in space.

Examples of learning activities

use dataloggers to investigate the displacement, velocity and acceleration of students as they perform long jumps and high jumps

investigate the relative speeds of carts or air table gliders

investigate the total momentum before and after various types of collisions between carts or air track gliders

use student designed crumple zones attached to motion trolleys to investigate inelastic collisions; the speed of the motion trolleys can be measured using ticker timers or dataloggers

discuss various measures to improve road safety from the point of view of the physics involved

throw a ball, and by measuring the range and time of flight calculate the initial velocity and maximum height

using calculations, predict the horizontal range of a marble after rolling down a ramp and off a bench and compare this theoretical and ideal range with the experimental range observed, accounting for any discrepancies

model the motion of a car rounding a corner by investigating the relationship between speed and radius for a rubber stopper moving in a circular path on the end of a length of fishing line under constant tension

swing a stopper attached to the end of a piece of string in a horizontal circle at different speeds and in a vertical circle to qualitatively explore apparent weight through the tension experienced in the string

use photography or other means to determine the angle of lean of a bicycle rider negotiating a curve of known radius at a constant known speed; compare the measured and calculated angles

develop a spreadsheet that models the motion of a sky diver approaching terminal velocity

use a set of bathroom scales in a lift to determine the change in apparent weight and hence the acceleration of the lift

select data on planets and their moons and use a spreadsheet to investigate gravitational and circular motion relationships

find data on the orbits of artificial satellites from the Internet and use it to determine the mass of the Earth

investigate impulse by dropping eggs onto different surfaces and also throwing eggs at a sheet under a variety of tensions

using a datalogger, investigate the nature of the friction force between two surfaces; produce a graph of the data and discuss

Detailed example

FACTORS AFFECTING FRICTION

The object under investigation will be made to accelerate by attaching a set of slotted masses via a fishing line and pulley. The object will also experience a retarding frictional force with the surface it is moving on.

Select one variable for your object that can be changed independently (e.g. mass, surface area, surface type).

Use a ticker timer or a datalogger to measure the average acceleration of the object and use Newton's second law to calculate the friction force acting on the object. Obtain a set of data for the friction force acting as you systematically vary the variable quantity that you are investigating.

Produce a graph of your data and make meaningful comments that can be supported by this graph about the effect of that variable on the friction force.

AREA OF STUDY 2: Electronics and photonics

Outcome 2

Investigate, describe, compare and explain the operation of electronic and photonic devices, and analyse their use in domestic and industrial systems.

Examples of learning activities

perform simple DC experiments with combinations of ohmic and non-ohmic circuit elements in series and parallel; measure the voltages and currents and compare them to the predictions from basic circuit theory

use an AC source with simple circuits and investigate the voltages across circuit elements with a cathode ray oscilloscope

use a circuit analysis program to investigate the characteristics of circuits containing various combinations of elements

construct a model circuit containing a light dependent resistor; investigate the effect of changing ambient light conditions on the resistance

use a cathode ray oscilloscope to investigate the input and output voltage characteristic of a voltage amplifier

investigate the transmission of laser light through optical fibres and wave guides

explore the concept of information, bandwidth and the rate at which information can be sent via various media

construct a simple device, using LEDs or lasers, to convert electrical signals into modulated light signals

search the Internet for applications of fibre optics

construct a simple circuit using a LDR or other photosensitive device to detect light signals and convert them into electrical signals; use this in conjunction with the previous device to transmit and receive a light signal

Detailed example

THE TRANSMISSION OF INFORMATION USING LIGHT

Construct a simple modulated light transmission and reception device. There are many ways to make such a device. The output of a signal generator can be carefully adjusted so that it will safely operate a LED. A suitable resistor in series with the LED will provide some protection against overload.

The simplest detector is probably a photovoltaic solar cell with the output connected, via a capacitor, to an amplifier connected to a loudspeaker.

A lens system or fibre optic cable could be used to extend the range of the device.

The signal can be modulated either by adjusting the frequency or amplitude manually or by using more complex electronic arrangements.

For one way of constructing a similar voice modulated device, see *The Physics Teacher* September 2002.

Unit 4

AREA OF STUDY 1: Electric power

Outcome 1	Examples of learning activities
Investigate and explain the operation of electric motors, generators and alternators, and the generation, transmission, distribution and use of electric power.	use iron filings and/or small compasses to investigate the shape of magnetic fields surrounding permanent magnets, current carrying conductors and solenoids use the magnetic field of a solenoid in conjunction with a current balance to confirm $F = I\ell B$ demonstrate the motor effect using a permanent magnet and a current carrying conductor; predict which way the conductor would move using the right-hand rule and test prediction demonstrate electromagnetic induction by changing the magnetic flux threading a solenoid demonstrate and seek explanations of the motion of the speed of a magnet falling in a long metal cylinder use Lenz's Law to predict the direction of an induced current when a magnetic field is produced inside a solenoid (either with a permanent magnet or another solenoid) use the magnetic field of a solenoid in conjunction with a 'tuning eye' radio valve to investigate the motion of electrons in a magnetic field analyse a low-voltage model of a transmission system compare the power produced by a DC voltage with that produced by an AC peak voltage of the same, twice and $\sqrt{2}$ times the DC voltage construct a concept map expressing the relationships between the main electromagnetic concepts search the Internet for information on different types of AC generation power plants find out why there is a proposal to build a DC power transmission link across Bass Strait to link Tasmania's electricity grid to the mainland build an electric motor; through research on the Internet and other sources investigate the efficiency of an electric motor compared with other motors

Detailed example

BUILD AND INVESTIGATE AN ELECTRIC MOTOR

Illustrate the concept of an electric motor with the construction of a simple model.

Create a rotor by winding enamelled copper wire lengthwise around a cork; leave enough length in the wire to bare the wire and form the commutator.

Use dressmaker pins to form a cradle for the rotor and to form the brushes.

Connect a battery to the brushes and place permanent magnets close to the rotor enabling the motor to spin.

Investigate the efficiency of an electric motor through research and comparisons of data with mechanical and other motors.

AREA OF STUDY 2: Interactions of light and matter

Outcome 2

Use wave and photon models to analyse, interpret and explain interactions of light and matter and the quantised energy levels of atoms.

Examples of learning activities

observe the colour of hot objects as the temperature increases and relate this to the concept of black body radiation

create an interference pattern on a screen using a diffraction grating

observe and describe the diffraction and interference effects as light passes through narrow single and double slits

investigate the triggering voltage for different coloured LEDs and relate this to the wavelength of the light

carry out a practical activity on the photoelectric effect using standard equipment and filters

use an applet to simulate a photoelectric circuit and the effect of changing the frequency and brightness of light

complete a written report based on a *New Scientist* or *Inside Science* article on the wave-particle model of light

illustrate the idea of the three-dimensional electron standing waves in an atom with two-dimensional standing waves in water or a metal 'Chladni' plate

use a diffraction grating to observe the line spectrum of a hydrogen discharge tube and relate the colour to the frequency of the light, hence calculate the photon energy

use data of retarding voltage and frequency for a selection of metals to explore the photoelectric effect; graph using paper or spreadsheet

Detailed example

LIGHT AND MATTER DATA ANALYSIS

Provide students with a set of data from a photoelectric experiment, namely, kinetic energy of photoelectrons and frequency of incident light. This could be real data, such as that obtained by Millikan in his 1914 experiment, or data prepared and provided by the teacher.

Students produce a graph of E_k versus frequency on graph paper or a spreadsheet.

This graph can be used to obtain or calculate secondary data such as the threshold frequency, work function and Planck's constant.

Alternatively, various photoelectric effect simulations are available on applets on the Internet.

DETAILED STUDY 3.1: Einstein's special relativity

Outcome 3.1

Use Einstein's theory of relativity to describe and explain relativistic motion and effects, and make comparisons with classical descriptions of motion.

Examples of learning activities

use a video camera to photograph motion from different frames of reference, e.g. a student walking along throwing a ball in the air from a stationary camera and from a moving camera, or motion on a rotating table

explore Newton's writing on the concepts of absolute space and time

research the dilemma physicists faced when trying to understand the medium in which electromagnetic waves travelled, the concept of an aether and its relationship to the question of an absolute frame of reference

use mathematical or physical modelling to explore the implications of the Michelson–Morley experiment

discuss some of the far-reaching implications of Einstein's two apparently simple postulates of special relativity

derive the time dilation equation from the theory of the light clock

use mathematical modelling to examine the way in which the correction factor $\gamma = 1/(1 - v^2/c^2)^{1/2}$ changes with speed

discuss the implications of the fact that the correction factor $\gamma = 1/(1 - v^2/c^2)^{1/2}$ approaches infinity at the speed of light including that the apparent mass of an object must also approach infinity

examine the experimental evidence that time runs more slowly for fast moving objects

discuss the philosophical implications of the relativity of space and time, notably the breakdown of Newton's 'clockwork universe'

use mathematical modelling of the flashlight in the train example (including constructing a spreadsheet table) to illustrate that non-simultaneity is a consequence of Einstein's postulates

Detailed example

CALCULATING THE SPEED OF LIGHT

It is helpful to imagine the speed of light slowed down to everyday speeds to get a feel for the implications of its constancy. For example, if we assume a speed of light of 30 m/s and a train carriage 60 m long moving at 10 m/s, it is quite easy to calculate that while an observer at the centre of the carriage will see the light flash from a lamp in the centre of the carriage return after 2.0 seconds, an observer watching from outside the train will see the same event take 2.25 seconds. (Remember that the speed of light is the same for both observers.)

Having done this simple calculation manually, the student can then construct a spreadsheet table in which the variables can be changed and the appropriate times calculated automatically. More realistic values of the quantities involved can then be found and the ratio of the two times found. These can then be compared to the $\gamma = 1/\sqrt{(1 - v^2/c^2)}$ correction factor.

DETAILED STUDY 3.2: Materials and their use in structures

Outcome 3.2

Analyse and explain the properties of construction materials, and evaluate the effects of forces and loads on structures and materials.

Examples of learning activities

analyse the forces in a simple structure supported by two top loading balances, each of which sits on a free-wheeling dynamics trolley

use the Internet to find data for strength; Young's modulus, and toughness of materials used for particular purposes such as building or aircraft construction

use the Internet to find details of the construction of particular bridges or buildings

look for websites which describe road safety issues in terms of the physics involved

invite a mechanical engineer to talk about his/her work

use measured data to plot the stress–strain graphs of materials such as hair, copper wire, fibres

measure force-compression data for a variety of running shoe soles and hence estimate the force on the runner's foot while running; use the Internet to research properties of running shoes

Detailed example

AN EXPERIMENT ON THE PROPERTIES OF RUNNING SHOES

Construct a heel shaped from wood with a flat upper surface which can be loaded with bricks or other heavy objects. Some form of horizontal stabilisation will be required which will not significantly affect the load. Use a telemicroscope or similar to measure the amount of compression under a range of loads which will approximate the forces likely to occur in running.

Produce graphs of compression versus load for a variety of running shoes and look at the differences between the graphs.

Attempt to relate the differences to the particular properties or construction of the shoes. Are there significant differences between the expensive and the cheaper shoes?

See if you can find detailed information on the Internet about the physical properties of the soles of good running shoes.

DETAILED STUDY 3.3: Further electronics

Outcome 3.3

Design and investigate an AC to DC voltage regulated power supply system, and describe and explain the operation of the system and its components, and the effects of test equipment on the system.

Examples of learning activities

maintain a work book of short electronic practical exercises

investigate the output of a voltage divider circuit as the values of the two resistors are changed, for example, where one of them is a LDR

design and construct a circuit to measure and graph (on paper, calculator or computer) the I–V characteristics of a diode

explain the role of the diodes and capacitor in a rectifier circuit

become familiar with the various functions and types of multimeters

use a cathode ray oscilloscope to observe the voltage output of a half or full wave rectifier circuit

find a fault in a pre-prepared circuit containing several elements

use a spreadsheet or electrical simulation program to model the charging and discharging of a capacitor in an R-C circuit

investigate the environmental impact of the widespread use of electronic equipment which often has a short useful lifetime

construct a circuit containing a resistor and a smoothing capacitor; use a cathode ray oscilloscope to analyse the smoothed output and view the effect of changing resistance and capacitance; use a spreadsheet to tabulate data

Detailed example

MEASURING THE TIME CONSTRAINT FOR A RESISTOR-CAPACITOR CIRCUIT

Create a circuit containing a large value capacitor in series with a DC power supply, a high value resistor, and a switch. Place a cathode ray oscilloscope across the capacitor.

Use a stopwatch to measure the time taken to reach a certain voltage and record these. Change the target voltage and repeat the procedure until you have sufficient data to produce a reliable graph of time versus voltage across the capacitor.

Produce a graph of voltage versus time for this data. The time taken for the capacitor to reach 63% of the supply voltage is the time constant. Compare your value with that obtained from the product of the nominal values of the capacitor and resistor.

You may use a spreadsheet to tabulate and graph this data.

DETAILED STUDY 3.4: Synchrotron and its applications

Outcome 3.4

Describe the basic design and operation of The Australian Synchrotron and the production, characteristics and interactions with targets of synchrotron radiation.

Examples of learning activities

investigate the problems of accelerating electrons to velocities near the speed of light; make feasibility calculations of the amount of energy required

make feasibility calculations of the strength of the magnetic field needed to keep electrons in the storage ring at particular radii (use realistic momentum values)

discuss diffraction from many layers in a crystal and hence derive Bragg's Law

use the Internet to compare the structure and operation of The Australian Synchrotron with another synchrotron

simulate Bragg diffraction by using microwave apparatus on a 'crystal' of ball bearings embedded in an array in a foam block

prepare a case study of a material investigated using X-ray microscopy and X-ray imaging

describe types of X-ray scattering and their relevance to the use of the synchrotron

explain applications of synchrotron radiation used to investigate the structure of materials

use supplied data from an educational synchrotron beamline website to investigate the structure of a crystal

Detailed example

INVESTIGATE THE STRUCTURE OF CRYSTAL

Investigate the structure of a crystal by using supplied data from a synchrotron beamline:

- select a crystal in terms of properties of interest to students
- download data from the synchrotron educational website
- use the data and Bragg's Law to determine the spacings between the planes in the crystal.

DETAILED STUDY 3.5: Photonics

Outcome 3.5

Apply the photon and wave models of light to describe and explain the operation of different light sources and fibre optic wave-guides, and analyse their domestic, scientific and industrial uses.

Examples of learning activities

look carefully at the light from a laser and explain the speckled effects as an indication of the coherent nature of the light

discuss the operation and use of a laser

make an inexpensive 'diffraction grating' spectrometer

make a fibre-optic voice transmission system with inexpensive plastic fibre and components

measure the wavelength of laser light using an interference pattern and a ruler

measure the width of a human hair using a laser version of Young's interference pattern

simulate a graded index light ray path using an Excel spreadsheet

use a laser pointer to measure the track spacing of a CD

Detailed example

USING A LASER TO MEASURE SMALL DISTANCES

Set up a laser pointer so that it creates a reflected diffraction pattern when shone on a CD. The pattern could be compared to that produced by a standard two slit slide or a transmission diffraction grating.

Investigate the nature of the pattern produced as the angle of the laser beam is altered. Explain the pattern as interference of light diffracted from each of the tracks on the CD. Set up the laser so that it strikes the disc at right angles and is reflected onto a screen that can be used to measure the angle of reflection of the several maxima which will be found.

Derive the formula $\sin\theta = n\lambda/d$ and use it to find d, the spacing of the tracks. The wavelength of the light can either be found from the specifications of the laser or by use of the two slit slide pattern.

Predict the diffraction pattern that would result from using a DVD instead of the CD. Observe the pattern produced and then explain the observation.

DETAILED STUDY 3.6: Sound

Outcome 3.6

Apply a wave model of sound and a field model of electromagnetism to describe, analyse and evaluate the recording and reproduction of sound.

Examples of learning activities

use a dB meter to measure sound levels at several distances from a loudspeaker on the school oval, and investigate how intensity varies with distance

use a frequency analyser to display and analyse the harmonics in the sound produced by a signal generator, tuning fork or musical instrument

estimate the dB level of a noisy classroom and then compare it with measurements from a dB meter

pull apart an old microphone or loudspeaker to investigate the way it works

use a frequency generator connected to a loudspeaker, in conjunction with a cathode ray oscilloscope and microphone (or accurate dB meter) to measure the frequency response of the loudspeaker

investigate the diffraction of sound of various frequencies as it passes through the door of a room

Detailed example

THE DIFFRACTION OF SOUND

Find a room that opens onto an environment where there is minimal reflection of sound. Alternatively, construct a box large enough to house a loudspeaker and cut a slit in one side. Use a frequency generator connected to the loudspeaker to produce monochromatic tones.

Either use a microphone connected to a cathode ray oscilloscope or another method of measuring the intensity of sound, to obtain data giving the intensity level of the sound at points on a semi-circular path of set radius around the opening.

Repeat the procedure for sound of a wide range of frequencies and produce graphs of the intensity as a function of the angle of the detector.

The experiment could then be repeated with different widths of slit, or of door opening.

Discuss the difficulties of obtaining ‘ideal’ results in an experiment like this.

SCHOOL-ASSESSED COURSEWORK

In Units 3 and 4 teachers must select appropriate tasks from the assessment table provided for each unit. Advice on the assessment tasks and performance descriptors to assist teachers in designing and marking assessment tasks will be published by the Victorian Curriculum and Assessment Authority in an assessment handbook. The following is an example of a teacher's assessment program using a selection of the tasks from the Units 3 and 4 assessment tables.

Outcomes	Marks allocated	Assessment tasks
Unit 3 **Outcome 1** Investigate motion and related energy transformations experimentally, and use the Newtonian model in one and two dimensions to analyse motion in the context of transport and related aspects of safety, and motion in space.	40	A student-designed extended practical investigation into selected aspects of energy and momentum transfers in collisions.
Outcome 2 Investigate, describe, compare and explain the operation of electronic and photonic devices, and analyse their use in domestic and industrial systems.	30	A written report on the combined use of electronic and photonic devices in a household alarm system.
Total marks for Unit 3	**70**	
Unit 4 **Outcome 1** Investigate and explain the operation of electric motors, generators and alternators, and the generation, transmission, distribution and use of electric power.	40	A summary report of selected practical activities from the student's logbook that demonstrates an electric power system and its use.
Outcome 2 Use wave and photon models to analyse, interpret and explain interactions of light and matter and the quantised energy levels of atoms.	30	A multimedia presentation that simulates photon emission and the photoelectric effect.
Detailed Study **Outcome 3.4** Describe the basic design and operation of The Australian Synchrotron and the production, characteristics and interactions with targets of synchrotron radiation.	30	Data analysis of beamline data supplied from a synchrotron database.
Total marks for Unit 4	**100**	