

## Science

### Physics

#### Rationale and aims

##### Rationale

The senior secondary Physics curriculum encompasses the three interrelated areas of science inquiry skills (incorporating skills and understanding of science as a way of knowing and doing), science as a human endeavour (incorporating knowledge and understanding of the personal, social, environmental, cultural and historical significance and relevance of science), and science understanding (incorporating knowledge and understanding of the biological, physical, and earth and space sciences). Building on students' science knowledge and skills acquired up to Year 10, the senior secondary Physics curriculum provides opportunities for students to think critically about the development of the fundamental laws and concepts of physics, and to apply these in a range of relevant and contemporary contexts and problems. Physicists play a key role in society in developing a range of technologies, in engineering, and in developing laws, models and theories that describe and explain how the world around us works. Physics applies to such diverse areas as renewable energy generation, communication, development of new materials, transport and vehicle safety, medical technology, understanding climate change and exploration of the universe. By studying the senior secondary Physics curriculum, students appreciate both the changing and expanding body of contemporary knowledge in physics, and the study of physics as an independent and collaborative human endeavour.

##### Aims

The aim of the senior secondary Physics curriculum is to provide students with a solid foundation in science knowledge, understanding, skills and values on which further learning and adult life can be built. Students should be able to:

- draw on their curiosity and willingness to speculate about and explore the world to expand their interest in physics
- plan and undertake practical and other research investigations involving collection, collation and analysis of qualitative and quantitative data, interpretation of experimental outcomes and the use of models and simulations to visualise, explore and explain events
- engage in communication of and about physics, value evidence and scepticism, and critically evaluate the scientific claims made by others
- solve problems, and make informed, responsible and ethical decisions when considering local and global issues and applications of physics concepts, techniques and technologies in daily life
- appreciate physics as both an independent and a collaborative human endeavour
- develop in-depth knowledge, understanding, skills and scientific values relating to physics
- appreciate the changing and expanding body of contemporary knowledge in physics.

## Organisation

### Content structure

The senior secondary Physics curriculum is organised around three interrelated strands: *Science inquiry skills*, *Science as a human endeavour*, and *Science understanding*.

#### *Science inquiry skills*

Scientific inquiry involves posing questions; formulating testable hypotheses; planning, conducting and critiquing investigations; collecting, analysing and interpreting evidence; and communicating findings. This strand is concerned with investigating ideas, evaluating claims, solving problems, drawing valid conclusions and developing evidence-based arguments. It also recognises that scientific explanations change as new or different evidence becomes available.

#### *Science as a human endeavour*

Science influences society through posing and responding to social and ethical issues, and science research is influenced by societal challenges or

social priorities. This strand highlights the need for informed, evidence-based decision-making about current and future applications of science. It acknowledges that, in making decisions about science and its practices, moral, ethical and social implications must be taken into account. This strand also acknowledges that science has been advanced through, and is open to, the contributions of many different people from different cultures at different times in history. It identifies the historical aspects of science as well as contemporary scientific issues and activities, and that science offers rewarding career paths.

### ***Science understanding***

An understanding of science is evident when a person selects and integrates appropriate science knowledge in ways that explain and predict phenomena, and applies that knowledge to new situations and events. Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established and continue to be challenged and refined by scientists over time. Science knowledge represents the building blocks of science understanding, but it is the dynamic nature of science understanding that will benefit citizens in an ever-changing world.

## **Links to K–10**

The senior secondary Physics curriculum builds on the knowledge and skills developed by students in science up to the end of Year 10 and extends their learning in the K–10 physical, earth and space sciences. The three organisational strands in Science K–10, *Science Understanding*, *Science as a Human Endeavour* and *Science Inquiry Skills* are continued into the senior secondary Physics curriculum. As with the Years K–10 science course, it is expected that teachers are able to show connections across these three strands in the exploration of ideas, concepts and principles. The inquiry approach to science fostered throughout Years K–10 is strengthened in the senior secondary years, with students formulating hypotheses generated from their own questions, and investigating and reporting on these. They also undertake an extended experimental investigation to explore an aspect of physics in depth.

## **Pathways**

The senior secondary Physics curriculum provides pathways for students wishing to pursue further studies or those wishing to enter the workforce. While students may choose to specialise in physics, synergies between the four senior science courses provide opportunities for students to pursue multidisciplinary areas of science in addition to studying specific concepts through different discipline lenses. Concurrent study of *Physics* and *Chemistry* provides opportunities for students to engage in creative problem-solving relating to issues in society, for example enhancing efficiencies of energy conversions, developing novel ways of conserving energy in local and global applications, using the spectroscopic analysis of light emitted by distant stars to predict the nature of matter in the universe and using nuclear reactions as alternative energy sources. Concurrent study of *Physics* and *Earth and Environmental Science* enables students to evaluate different viewpoints and to enhance their decision-making capacity related to issues of local concern, for example monitoring physical changes in the environment, sustainable use of natural resources, and energy conservation. The concurrent study of *Physics* and *Biology* may stimulate students' interest in astrobiology and nuclear medicine. In addition to providing pathways for further study or employment, the senior secondary Physics curriculum provides opportunities for all students to develop an understanding of physics concepts and principles which will enable them to become more informed citizens who are able to make evidence-based decisions about the science-related issues which arise in their lives.

## **Unit structure**

Content of the senior secondary Physics curriculum is outlined below:

### ***Unit 1: Motion and energy***

In this unit, students will use an inquiry approach to investigate and develop their understanding of motion and energy.

This will include the study of: the laws and equations which describe linear motion; the interaction of forces that cause motion; the conservation laws that apply within mechanical systems; the application of dynamics and conservation laws to systems; the use of a field model to represent and predict interactions with charged objects; the relationship between voltage, potential difference and current for materials; the design of household wiring to supply devices with the necessary energy input; significant developments resulting from the discovery of semiconductors; and the construction of simple electronic circuits for various uses.

Students will reflect on how knowledge in physics in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

### ***Unit 2: Radiation and nuclear physics***

In this unit, students will use an inquiry approach to investigate and develop their understanding of radiation and nuclear physics.

This will include the study of: the discovery that light was an electromagnetic wave; interactions between light and matter that involve the processes of reflection, refraction and absorption; different methods for encoding information for transmission using electromagnetic waves; experiments on diffraction and interference that provide definitive evidence for the wave model for light; applications of resonance produced by waves; the Doppler effect; the dependence of theories about the universe on information obtained using the electromagnetic spectrum; the nature of emissions by unstable nuclei; the discovery of particles using the laws of conservation of energy and momentum; the application of nuclear stability and related energy principles to explain the nuclear decay of unstable atoms; the production and uses of isotopes; and the physics underpinning the use of nuclear reactions to provide heat energy used to generate electricity.

Students will reflect on how knowledge in physics in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

### ***Unit 3: Space science***

In this unit, students will use an inquiry approach to investigate and develop their understanding of space science.

This will include the study of: projectile motion; the law of universal gravitation; circular motion; applications of the laws of conservation of momentum and conservation of energy to space travel; development and implications of Einstein's theory of special relativity; variations in the characteristics and lifetimes of stars; the significance of the Sun as the nearest star from Earth; and nuclear fusion reactions.

Students will reflect on how knowledge in physics in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

### ***Unit 4: Physical models and relationships***

In this unit, students will use an inquiry approach to investigate and develop their understanding of physical models and relationships.

This will include the study of: the production of forces by the interaction between moving charges and magnetic fields; the discovery of the electron; production of forces through interactions between current and magnetic fields; principles and applications of DC motors and AC induction motors; production and transmission of direct current and alternating current; development of a quantum theory of light; development of the atomic model; development of the laser; particle accelerators; the Standard Model; relationship between the Big Bang model of the universe and the Standard Model.

Students will reflect on how knowledge in physics in this area has developed, in addition to contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

## General capabilities

The Australian Curriculum, Assessment and Reporting Authority (ACARA) has identified 10 general capabilities that will be specifically covered in the curriculum. In the senior secondary Physics curriculum, eight of these are considered inherent to science and so are explicitly included in the content descriptions and achievement standards. These are literacy, numeracy, information and communication technologies (ICT), thinking skills, creativity, teamwork, ethical behaviour and self-management. Each of these is embedded in the content descriptions of the *Science inquiry skills* strand and many are also incorporated into the *Science as a human endeavour* strand.

*Literacy* is an important capability in physics. Students will be taught how to use correct scientific language, including correct units when describing methods, making and recording measurements, and writing conclusions and explanations. They will be required to communicate their knowledge within and beyond the physics community, selecting and using formats appropriate to a purpose and audience, including written texts, multimodal representations and oral presentations. They will access, critically read, and extract information related to physics from a variety of sources, and acknowledge these sources appropriately.

*Numeracy* knowledge and skills are used and developed within the physics course in a range of situations, often through the measurement and analysis of results from investigations, including where physical laws are validated with experimental results. Both qualitative and quantitative data will be collected and represented in appropriate formats. Students will be required to analyse numerical and graphical data in a range of situations, including the application of the laws of motion, energy, current electricity and forces which will include algebraic mathematical relationships used to calculate and predict values. Students will apply the concept of error and uncertainty to their results and will evaluate the reliability of measurements in first- and second-hand data. They will be required to use skills of statistical analysis when using data from both their own experiments and secondary sources. Students will be required to apply the concept of exponential decay and have an understanding of a range of scales used to measure time and distance.

*Information and communication technologies (ICT)* are relevant to teaching and learning in a large part of the senior secondary Physics curriculum. This will include the use of the internet to research concepts and applications as well as the use of digital learning objects such as animations and simulations to enhance students' understanding and engagement in physics. The use of the internet and local networks will facilitate a collaborative approach among students that models the methods of modern science. In practical investigations, ICT will aid students in tasks such as data collection and analysis through the use of probeware such as temperature, current, potential difference, time and radiation, and the use of spreadsheets. This enables students to use and analyse results efficiently, allowing for the development of valid conclusions, and also allows access to other potential areas for investigation. Simulations and modelling using digital technologies provide students with opportunities to experience situations which cannot be investigated through practical experiments in the classroom, especially in the area of space science and nuclear physics. ICT offers opportunities to provide a range of media for communicating and sharing students' ideas and understandings both within and beyond the classroom.

*Thinking skills* are integral to the development of understanding in physics, including the ability to pose questions, make predictions, speculate, solve problems through investigation, make evidence-based decisions, analyse and evaluate evidence from their own and others' work and summarise information. Students will be encouraged to plan and conduct practical investigations as well as to select appropriate information from secondary sources and to evaluate the sources of information used to formulate conclusions. Students will also develop skills to evaluate claims based on the physical sciences, for example in the media and advertising.

*Creativity* enables the development of ideas that are new to the individual. Students will develop skills that will enable them to formulate creative questions, speculate, think in new ways about observations of the world around them and suggest solutions to physics-based problems. In this course some of the students' understandings of the world around them will be taken to a deeper level, involving the development and amendment of existing understandings. Students will be encouraged to be flexible and open-minded as their own understandings of physical concepts change and develop. Creative approaches to problem-solving may also be applied when students are required to perform experiments using new methodologies or limited resources. For example, they may be required to develop equipment that allows them to test the relative effectiveness of different materials in cushioning collision impacts.

*Self-management* is intrinsic to the ability to effectively carry out experiments and investigations. Specific self-management skills will be developed as students are encouraged to plan effectively for individual and collaborative activities, and when they reflect on their own practices and learning. In this course the degree of guidance given to students will be reduced when compared with that experienced in earlier stages of schooling, requiring

that students work as independent learners.

*Teamwork* is an important aspect of science at a number of levels, both personal and organisational. At times students will be required to work together, sharing ideas and discussing and debating their work in order to develop and consolidate their knowledge. They will study examples of physicists working in teams, both harmoniously and discordantly, to develop ideas in physics or undertake research in a specific branch of physics. The focus in this course will be on developing harmonious, collaborative methods of student inquiry in their own learning and for future work applications.

*Ethical behaviour* is considered in relation to both experimental science and the acquisition and use of scientific information, including when working independently, in teams or in an online environment. In carrying out investigations students are encouraged to gather evidence honestly and ethically, considering the implications of the investigation. Students will also develop skills to evaluate claims based on science. This will enable them to make more valid judgments about social, environmental and personal issues that involve physics. There will also be opportunities for students to discuss the ethical implications of applications of physics in areas such as energy production (including nuclear energy), transport and communication technologies.

## Cross-curriculum dimensions

The cross-curriculum dimension of sustainability is addressed in the content descriptions of the senior secondary Physics curriculum. Knowledge and understanding of the natural environment is incorporated within the content descriptions for the *Science understanding* strand. It includes energy conservation, and comparison of energy efficiencies of electrical devices and electricity generation. Sustainability as a social and environmental issue is incorporated in the *Science as a human endeavour* strand in areas such as energy conservation and alternatives to fossil fuels. Important skills associated with sustainability, including researching areas such as electricity generation and evaluating claims and arguing ideas, are incorporated within the *Science inquiry skills* strand.

Curriculum content that relates to Indigenous history and culture is represented in the content descriptions of the senior secondary Physics curriculum. The Science as a human endeavour strand explicitly refers to the range of explanations for the origin of the universe, solar system and Sun by different cultural groups.

The cross-curriculum dimension Asia and Australia's engagement with Asia provides engaging and rich contexts for science learning.

## Unit 1 - Motion and energy

In this unit, students will use an inquiry approach to investigate and develop their understanding of motion and energy. This will include the study of: the laws and equations which describe linear motion; the interaction of forces that cause motion; the conservation laws that apply within mechanical systems; the application of dynamics and conservation laws to systems; the use of a field model to represent and predict interactions with charged objects; the relationship between voltage, potential difference and current for materials; the design of household wiring to supply devices with the necessary energy input; significant developments resulting from the discovery of semiconductors; and the construction of simple electronic circuits for various uses. Students will reflect on how knowledge in physics in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

### Science understanding

The laws and equations which describe linear motion, including:

- linear uniform motion and uniform acceleration
- equations of uniformly accelerated motion to quantify motion
- use of SI units to quantify descriptions of uniform and uniformly accelerated motion
- representation of vector and scalar quantities
- graphical representation and analysis of motion
- measurement of acceleration due to gravity
- determination of the motion of one moving object relative to another moving object.

The interaction of forces which cause motion, including:

- identification of the four fundamental forces, and their related properties and processes
- the generation of contact forces and frictional forces from electrical interactions
- interpretation of observations of everyday motion using Newton's three laws of motion
- the difference between mass and weight
- description of a system which is in equilibrium
- the conditions for, and the nature of, simple harmonic motion.

The conservation laws which apply within mechanical systems, including:

- the relationship between work, energy and force, including how work must be done to overcome frictional forces
- the definition of power as the rate at which work is done
- force versus displacement graphs, including the area under the curve as a representation of work
- energy conversions involving gravitational potential energy, kinetic energy, elastic potential energy and heat
- application of the laws of conservation of momentum and energy in collisions
- conservation of energy for a free-falling body and for a system undergoing simple harmonic motion
- calculation of energy efficiency for any process that converts one form of energy into another
- energy loss (for example, by friction).

Applications of dynamics and conservation laws, including:

- energy conservation in a range of situations (for example, individual living organisms, ecosystems, the energy balance of Earth)
- the spatial distribution of solar radiation and the resulting large-scale circulation of the atmosphere and oceans.

The use of a field model to represent and predict interactions between charged objects, including:

- the nature of the force between two point charges (Coulomb's law)
- the representation of the electric field pattern around and between charges and between charged parallel plates
- definitions of electric field strength and electric potential difference
- the force on a charge in an electric field.

The relationship between voltage, potential difference and current for materials, including:

- the use of Ohm's law and its limitations
- conduction in metals and the production of heat energy by electric currents
- energy losses in the transport of electricity
- the effect of temperature on the resistance of metals, including superconductivity
- the conduction of electric current through pure semiconductors

- the effect of temperature on the resistance of pure semiconductors.

The design of household wiring to supply devices with the necessary energy input, including:

- the rate at which electrical energy is supplied
- power and the power rating of household devices
- the use of parallel circuits for wiring and the need for different lighting, power and dedicated circuits
- comparison of the energy efficiencies of incandescent, fluorescent and light emitting diodes as light sources
- comparison of the efficiencies of a direct electric heater and an electric heat pump.

Significant developments resulting from the discovery of semiconductors, including:

- the nature of doped p- and n-type semiconductors
- the embedding of complex circuits onto a single piece of semiconducting material
- the operation and use of semiconductor junctions, diodes (including light emitting diodes) and solar cells in important applications of semiconductors.

The construction of simple electronic circuits for various uses, including:

- the use of capacitors in DC circuits for storing energy
- the use of a rectifier circuit to convert AC to DC
- the use of an inverter circuit to convert DC to AC
- the construction of a simple amplifier circuit using a transistor and an operational amplifier
- the operation of electrical systems in the home (for example, lighting and power circuits, dimmer switches and security light sensors).

## Science as a human endeavour

The nature and practice of physics, including:

- the dynamic nature of the body of knowledge in physics which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improves
- examples of applications of knowledge of forces and motion in careers and recreational pursuits from a range of fields (for example, mechanical and civil engineers, accident investigators, sportspersons, meteorologists, aircraft pilots)
- examples of applications of knowledge of electricity and electronic circuits in a range of careers and recreational pursuits (for example, electricians, electronics home hobbyists, electrical engineers, robotics engineers, stage set designers).

Contemporary research and applications of physics, including:

- designing and improving the safety and energy efficiency of modes of transportation (for example, planes, ships, cars, trains)
- examining large-scale sources of electrical energy and the different mix of energy sources used by countries
- improving efficiency of energy conversion processes (for example, in heating, cooling, lighting and transport) and the importance of electrical

energy efficiency in minimising resource use

- developments in technology (for example, solar cells) which have led to the production of sustainable energy sources
- conversion of AC to DC (and vice versa) for use in everyday devices (for example, calculators; music players; airconditioners and heaters; home energy systems using wind generators, photovoltaic and battery combinations)
- developments in components that have led to many important applications (for example, the operation of camera flash and digital imaging systems; diode lasers in DVD players; replacement of metal with lighter carbon composites in cars, planes and sporting equipment).

The development of ideas in physics, including:

- the historical contribution of experiments (for example, Galileo's experiments with rolling balls, free-falling objects and pendulums; Newton's observations and use of mathematics to describe motion; Ohm's experiments on electrical resistance; Faraday's use of the field concept to describe electric and magnetic forces)
- research that has led to our current knowledge of semiconductors, their properties and uses, and the contributions and human stories of some of the key physicists involved in this research (for example, Shockley, Brattain, Bardeen, Kirby).

### Science inquiry skills

Design and perform investigations and experiments related to motion and energy, considering relevant aspects of safety, methodology and ethics, including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations include:

- investigating the relationship between force, mass and acceleration
- measuring the acceleration due to gravity
- investigating Hooke's law
- investigating the variables that determine the period of a system undergoing simple harmonic motion
- comparing mathematical and experimental results for the conservation of momentum in a variety of collisions
- measuring the power developed by a student when accelerating from rest and when climbing stairs
- investigating conservation of energy (for example, through Galileo's pin and pendulum experiment)
- investigating Ohm's law
- measuring the temperature dependence of resistance for a conductor and semiconductor
- building and testing simple circuits such as a rectifying circuit, a light-emitting diode and an amplifying circuit using an operational amplifier.

Perform investigations and experiments, including:

- using physics concepts to generate questions and guide the construction of hypotheses that inform the design of investigations
- selecting and using appropriate equipment for a specific task (for example, data loggers, video cameras, stroboscopic photography apparatus, photogates, masses, stopwatches, measuring tapes, electrical resistors, voltmeters, ammeters, multimeters, capacitors, light emitting diodes, operational amplifiers, solar cells, power sources)
- collecting and recording first- and second-hand data using appropriate formats and ICT
- accessing, critically reading and extracting information from a variety of texts, and referencing sources appropriately

- analysing quantitative data using mathematical and/or graphical methods, including plotting of measurements and their uncertainties, comparisons with quantitative predictions of simple numerical models, and quantitatively validating some of the physical laws with experimental results
- developing an understanding of the relationship between algebraic and graphical representations of mathematical relationships in physics
- including uncertainties in measurements
- formulating explanations and conclusions based on experimental evidence
- evaluating methods employed in investigations and suggesting specific changes to improve the accuracy of results.

Engage in critical, creative, innovative and reflective thinking, including:

- evaluating the validity of varying scientific results and scientific arguments
- applying the laws of physics to predict the behaviour of physical phenomena and systems
- using probabilities and models to make predictions about future events (for example, weather, likelihood of road accidents)
- proposing new questions for investigation and innovative solutions to problems related to physics
- generating ideas, plans, processes and/or products to solve problems and to challenge current thinking
- considering the role of uncertainty in data when testing a scientific model or investigating a scientific phenomenon.

Analyse and synthesise information relating to physics, including:

- researching, selecting and synthesising relevant information from a range of sources, and referencing sources appropriately
- using and interpreting scientific models and simulations to aid understanding and communication of physics concepts
- evaluating claims in advertising and the media.

Communicate ideas and findings, including:

- creating and presenting structured reports of experimental and investigative work
- discussing results and findings with others to develop understanding
- using correct scientific language, including correct units when describing methods, making and recording measurements, and writing explanations and conclusions
- using correct physics representations, including drawing field lines to represent the direction and intensity of electric fields, and drawing and interpreting circuit diagrams and wire circuits that do useful things
- sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and information security
- explaining concepts and debating issues related to physics to a range of audiences.

## Unit 2 - Radiation and nuclear physics

In this unit, students will use an inquiry approach to investigate and develop their understanding of radiation and nuclear physics. This will include the study of: the discovery that light was an electromagnetic wave; interactions between light and matter that involve the processes of reflection, refraction and absorption; different methods for encoding information for transmission using electromagnetic waves; experiments on diffraction and interference that provide definitive evidence for the wave model for light; applications of resonance produced by waves; the Doppler effect; the

dependence of theories about the universe on information obtained using the electromagnetic spectrum; the nature of emissions by unstable nuclei; the discovery of particles using the laws of conservation of energy and momentum; the application of nuclear stability and related energy principles to explain the nuclear decay of unstable atoms; the production and uses of isotopes; and the physics underpinning the use of nuclear reactions to provide heat energy used to generate electricity. Students will reflect on how knowledge in physics in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

### Science understanding

The discovery that light was an electromagnetic wave, including:

- Maxwell's prediction of the existence of electromagnetic waves
- Hertz's experimental validation of Maxwell's electromagnetic wave prediction.

Interactions between light and matter that involve the processes of reflection, refraction and absorption, including:

- the relationship between colour and the absorption, reflection and transmission of different frequencies of light
- the difference between specular and diffuse reflection (scattering)
- use of the wave model to explain refraction (Snell's law)
- the conditions under which total internal reflection occurs
- the application of total internal reflection in fibre optics.

Different methods of encoding information for transmission using electromagnetic waves, including:

- comparison of amplitude modulation (AM) and frequency modulation (FM)
- operational uses of digital radio and television.

Experiments on diffraction and interference that provide definitive evidence for the wave model for light, including:

- the diffraction of light and other electromagnetic waves
- support for a wave model for light through the interference patterns produced by the superposition of light waves (Young's double slit experiment and thin film interference).

Applications of the resonance produced by waves, including:

- conditions required for resonance to occur
- resonance in microwave ovens to heat food
- the greenhouse effect as a consequence of the resonance frequencies of molecules in Earth's atmosphere.

Occurrence of the Doppler effect, including:

- use of the Doppler effect for sound waves in medical ultrasound imaging
- production of the Doppler effect using light waves (red and blue shift) in terms of photon energy and what the effect tells us about the motion of stars and galaxies.

The dependence of theories about the universe on information obtained using the electromagnetic spectrum, including:

- the roles of terrestrial and extraterrestrial telescopes, and the types of radiation collected
- the Big Bang theory and the evidence that supports the theory, including galactic red shift and cosmic background radiation.

Properties and uses of emissions produced by unstable nuclei, including:

- the properties of alpha, beta and gamma radiations and the methods of discovery of these forms of radiation
- the interaction of alpha, beta and gamma radiation with matter, including the ionisation of atoms, the absorption as a function of distance travelled through matter and the differences in their absorption by different materials
- the positron decay of artificial isotopes and the use of these particles in medical imaging (including Tc-99m (gamma source) and fluorine-18 (a positron emitter)).

The discovery of particles using the laws of conservation of momentum and energy, including:

- discovery of the neutron and the neutrino
- the application of the laws of momentum and energy in the analysis of data from accelerators such as those at Fermilab and the Large Hadron Collider.

The application of nuclear stability and related energy principles to explain the nuclear decay of unstable atoms, including:

- calculation of the binding energy of a nucleus and interpretation of the binding energy per nucleon graph
- nuclear decay equations for alpha, beta and gamma radiations
- interpretation of a half-life graph for nuclear decay and the significance of the half-life of a radioisotope
- the use of isotopes in dating objects and materials.

The production and uses of radioisotopes, including:

- specific examples of radioisotopes with medical and industrial applications (for example, the use of cyclotrons to produce medical isotopes; the use of nuclear reactors, including the OPAL reactor, to produce isotopes)
- the physical basis of biohazards of alpha, beta and gamma rays, and the precautions used to protect living organisms from these effects.

The physics underpinning the use of nuclear reactions to provide heat energy used to generate electricity, including:

- nuclear processes which produce alpha, beta and gamma radiation
- the production of energy through nuclear fission and nuclear fusion reactions
- calculations of the mass defect in nuclear fission and fusion reactions
- use of Einstein's mass-energy equivalence equation to determine the energy produced or absorbed in nuclear reactions.

## Science as a human endeavour

The nature and practice of physics, including:

- the dynamic nature of the body of knowledge in physics which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improves
- the role of physicists in developing new technologies such as medical and industrial applications of radioisotopes
- the importance of an understanding of the nature, properties and effects on living cells of different types of radiation in the development of legislated workplace practices regarding the production, handling and transport of radioactive materials
- the use of radiometric dating in establishing the geological time scale and for finding the age of archaeological artefacts.

#### Contemporary research and applications of physics, including:

- methods being investigated to initiate and contain nuclear fusion reactions on Earth
- medical and industrial applications of nuclear radiation (for example, cyclotrons which are used to produce positron-emitting isotopes to improve the diagnosis of certain diseases)
- nuclear fusion reactions as an alternative energy source to fossil fuels
- the Australian Synchrotron and the production of electromagnetic radiation for research purposes
- the importance of electromagnetic radiation for our daily lives through applications in communications technologies, and the construction of Earth-based and space telescopes and telescopic arrays which detect radiation, enabling scientists to better understand the universe.

#### The development of ideas in physics, including:

- the replacement of the geocentric model for the solar system by the heliocentric model as a result of the development of the telescope, and Galileo's use of telescopic observations to support the heliocentric model of the solar system
- the contribution of historical experiments to our understanding of nuclear physics (for example, Max von Laue's and Bragg's work on X-ray crystallography, Becquerel's discovery of beta radiation, Rutherford's discovery of alpha radiation, Marie Curie's discovery of radium, the work of Lise Meitner and Otto Hahn on nuclear fission)
- historical experiments and human stories related to the development of ideas in nuclear physics which demonstrate application of scientific values and endeavour (for example, Maxwell's prediction of the existence of radio waves and their subsequent confirmation by Hertz; Bragg's experiments with diffraction of X-rays by crystals, which were subsequently used to investigate the structure of crystalline substances, including DNA)
- increased understanding of the nature of matter informed by experiments related to the changes undergone by unstable nuclei to produce different types of emissions
- the application of the fundamental laws of conservation of mass and energy that led to important discoveries (for example, prediction of the neutrino by Pauli; Fermi's first demonstration of a nuclear chain reaction; Paul Dirac's prediction of the positron and its subsequent discovery by Carl Anderson; Chadwick's discovery of the neutron)
- research that has led to our current knowledge of energy production from nuclear reactions (for example, the Manhattan project which led to the development of the atomic bomb; nuclear fission reactors and attempts to develop nuclear fusion reactors)
- changes in the way we communicate as a result of developments in optics, including the use of fibre optics and lasers for long-distance communication, and the impact of optical data storage on entertainment and education.

### Science inquiry skills

Design and perform investigations, experiments and simulations related to radiation and nuclear physics, considering relevant aspects of safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations include:

- producing and detecting radio waves
- measuring the refractive index of a transparent material
- measuring the critical angle for a transparent material
- investigating resonance (for example, by using coupled pendulums of various lengths)
- measuring the wavelength of emission from a laser pointer and spectral lamp using interference
- observing alpha and beta particle tracks with a cloud chamber
- investigating absorption of alpha, beta and gamma rays by a variety of materials
- simulating the decay of a radioactive isotope and measuring its half-life.

Perform investigations and experiments, including:

- designing valid investigations to test hypotheses
- selecting and using scientific equipment appropriate to the task (for example, data loggers, lasers, optical fibres, double and single slits, monochromatic light sources, DVDs as optical gratings)
- collecting and recording first- and second-hand data using appropriate formats and ICT
- analysing quantitative data using mathematical and/or graphical methods
- proposing and testing mathematical models for data (for example, linear, inverse, inverse square relationships)
- accessing, critically reading and extracting information from a variety of texts, and referencing sources appropriately
- developing an understanding of the relationship between the algebraic and graphical representations of mathematical relationships
- estimating the uncertainty of data in quantitative measurements
- evaluating methods employed in investigations and suggesting specific changes to improve the accuracy and reliability of results
- formulating explanations based on experimental evidence.

Engage in critical, creative, innovative and reflective thinking, including:

- evaluating the validity of scientific arguments
- evaluating the validity of a scientific investigation, including the validity of measurements, procedures and models used in the investigation
- generating ideas, plans, processes and/or products to solve problems and to challenge current thinking
- using probabilities in models about future events (for example, half-life in radioactive decay, lifetime of isotopes)
- recognising the importance of uncertainty in data when testing a scientific model.

Analyse and synthesise information relating to physics, including:

- evaluating the accuracy of claims related to radiation and nuclear physics in advertising and the media
- researching, selecting and synthesising relevant information from a range of sources, and referencing sources appropriately

- using and interpreting scientific models and simulations to aid understanding and communication of physics concepts.

Communicate ideas and findings, including:

- creating and presenting structured reports of experimental and investigative work
- discussing results and findings with others to develop understanding
- using scientific language when describing methods, conclusions and explanations
- sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and information security
- explaining issues and concepts related to physics to a range of audiences.

### Unit 3 - Space science

In this unit, students will use an inquiry approach to investigate and develop their understanding of space science. This will include the study of: projectile motion; the law of universal gravitation; circular motion; applications of the laws of conservation of momentum and conservation of energy to space travel; development and implications of Einstein's theory of special relativity; variations in the characteristics and lifetimes of stars; the significance of the Sun as the nearest star from Earth; and nuclear fusion reactions. Students will reflect on how knowledge in physics in this area has developed, in addition to exploring contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

#### Science understanding

Projectile motion, including:

- the uniform force that acts on a projectile near Earth's surface
- resolution of velocity and force into vertical and horizontal vector components
- applications of the equations of uniformly accelerated motion to calculate maximum height reached, time of flight, range and velocity at a particular time during flight
- the limitations of the projectile motion model, which makes the assumption that the force due to gravity is uniform rather than radial.

The law of universal gravitation, including:

- the nature and magnitude of the gravitational force between masses
- acceleration due to gravity and weight
- the representation and modelling of the gravitational field of a body, such as Earth
- the concept and definition of gravitational potential energy
- the law of conservation of energy applied to falling objects, projectiles and the concept of escape velocity
- comparison of models for gravitational potential energy, for objects at different distances above Earth's surface.

Circular motion, including:

- the centripetal force needed to maintain an object in a circular path or orbit
- the approximation of planetary orbits to circular orbits and Kepler's first and second laws of planetary motion

- acceleration due to centripetal force
- the relationship between the law of universal gravitation and Kepler's third law (law of periods)
- comparison of the motions of satellites (low earth orbit, geosynchronous and geostationary).

Applications of the laws of conservation of momentum and conservation of energy to space travel, including:

- use of the law of conservation of momentum to explain space travel events (for example, simplified force–acceleration relationship during rocket launch, the use of thrusters to change the direction of spacecraft)
- re-entry through Earth's atmosphere and strategies for making this safe, with reference to the law of conservation of energy
- comparison of propulsion systems and energy efficient strategies for launching spacecraft from Earth.

Development and implications of Einstein's theory of special relativity, including:

- the significance of the speed of light
- length contraction, mass increase, time dilation and mass/energy equivalence
- the validation and application of Einstein's theory of special relativity.

Variations in the characteristics and lifetimes of stars, including:

- the characteristics of different types of stars, including apparent magnitude, absolute magnitude, luminosity, surface temperature, colour, size, spectral class
- the scale of the universe and calculations of distance, including the use of parallax method for nearby stars and Cepheid variables for distant stars
- the relationship between Hertzsprung–Russell diagrams and the evolution of stars
- the relationship between masses of stars and their evolution and the evolution of the Sun.

The significance of the Sun as the nearest star from Earth, including:

- the solar energy output and the radiation intensity at the top of the atmosphere and at Earth's surface
- use of the solar constant and mass–energy equivalence to determine the mass lost by the Sun per second
- the cyclical nature and effects of sunspots
- the solar wind and its effects on satellites and Earth
- disruptions in communication due to solar activity.

Nuclear fusion reactions as the source of energy for stars to radiate electromagnetic radiation into space, including:

- the types of nuclear fusion reactions which occur in the stars
- production of heavy elements, including the role of supernovas.

## Science as a human endeavour

The nature and practice of physics, including:

- the dynamic nature of the body of knowledge in physics which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve
- explanation of everyday events by applying understanding of projectile and circular motion (for example, ball games; spinning fun park rides; launching missiles and rockets; cornering in a vehicle; actions of sportspeople such as pole vaulters, golfers, tennis players, springboard divers and ski jumpers)
- applications and examples of the effects of relativity and ways of validating this theory
- applications and value of satellites in communication, surveillance and astronomical research.

Contemporary research and applications of physics, including:

- designing propulsion mechanisms for spacecraft, such as 'photon sails' and ion propulsion systems
- investigations of the nature and variety of stars observed in the night sky, and monitoring changes in stars
- methods of detecting exoplanets (application of Doppler effect and light curve variation).

The development of ideas in physics, including:

- Galileo's analysis of projectile motion with reference to the importance of experimental data and his conclusions regarding the shape and independent vertical and horizontal motions of a projectile
- Maxwell's proposal of the existence of the aether as a medium for the transmission of electromagnetic waves, including the properties of the aether and their relationship to the observed properties of light
- historical experiments and human stories related to space science that demonstrate application of scientific values and endeavour (for example, Newton's work on universal gravitation and satellites; Michelson and Morley – the significance of the 'null result' of their experiment; Einstein – 'moving magnet and conductor' problem, and special relativity)
- range of explanations for the origin of the universe, solar system and Sun by different cultural groups
- the current and future roles of major observatories in collecting data from space and changing scientists' thinking about the universe (for example, Siding Spring Observatory, Culgoora Solar Observatory, Parkes Radio Telescope, Hubble Space Telescope, Atacama Large Millimeter Array, Mauna Kea Observatory, James Webb Space Telescope, Square Kilometre Array).

### Science inquiry skills

Design and perform investigations, experiments and simulations related to space science, considering relevant safety, methodology and ethics, and including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations include:

- verifying the independence of vertical and horizontal components and quantitative predictions related to projectile motion
- examining the acceleration of water rockets
- measuring the centripetal force on an object moving with uniform circular motion
- differentiating between inertial and non-inertial reference frames
- examining Hertzsprung–Russell diagrams for different star types and for globular and open clusters of stars.

Perform investigations and experiments, including:

- using physics concepts to generate questions and guide the writing of hypotheses that inform the design of investigations
- selecting equipment and materials appropriate to the task (for example, data loggers, video cameras, stroboscopic photography apparatus, stopwatches, measuring scales, appropriate projectiles, star charts, spectral charts of stars, star photographs)
- accessing, critically reading and extracting information from a variety of texts, and referencing sources appropriately
- estimating the uncertainty of data in quantitative measurements
- analysing quantitative data using mathematical and/or graphical methods
- proposing mathematical models for data (for example, linear, inverse, inverse square relationships)
- developing an understanding of the relationship between the algebraic and graphical representations of mathematical relationships in physics
- evaluating methods employed in investigations and suggesting specific changes to improve the accuracy and reliability of results
- formulating explanations based on experimental evidence.

Engage in critical, creative, innovative and reflective thinking, including:

- evaluating the validity of scientific arguments and results of scientific investigations, including the validity of measurements, procedures used, models and conclusions
- debating issues relating to space science (for example, government funding allocation for long-distance space travel)
- generating ideas, plans, processes and/or products to solve problems and to challenge current thinking
- using probabilities to assess risk (for example, the likelihood of Earth being hit by a meteorite, the nature and risks associated with travel on Earth and travel in space).

Analyse and synthesise information relating to physics, including:

- evaluating the accuracy of claims involving space science concepts made in advertising and the media
- researching, selecting and synthesising relevant information from a range of sources, and referencing sources appropriately
- using and interpreting models and simulations to facilitate understanding and communication of physics concepts.

Communicate ideas and findings, including:

- creating and presenting structured reports of experimental and investigative work
- discussing results and findings with others to develop understanding
- using correct scientific language when describing methods, conclusions and explanations
- sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and information security
- explaining concepts related to physics to a range of audiences.

## Unit 4 - Physical models and relationships

In this unit, students will use an inquiry approach to investigate and develop their understanding of physical models and relationships. This will include the study of: the production of forces by the interaction between moving charges and magnetic fields; the discovery of the electron;

production of forces through interactions between current and magnetic fields; principles and applications of DC motors and AC induction motors; production and transmission of direct current and alternating current; development of a quantum theory of light; development of the atomic model; development of the laser; particle accelerators; the Standard Model; relationship between the Big Bang model of the universe and the Standard Model. Students will reflect on how knowledge in physics in this area has developed, in addition to contemporary research and applications. They will undertake a range of investigations and experiments to develop and apply their inquiry skills, and will complete an extended experimental investigation.

### Science understanding

Production of forces by the interaction between moving charges and magnetic fields, including:

- the magnitude and direction of the force acting on a charge moving in a magnetic field
- prevention by Earth's magnetic field of high-energy charged particles (mainly protons) from reaching its surface.

Discovery of the first sub-atomic particle, the electron, including:

- properties, behaviour and nature of cathode rays as deduced from experiments
- Thomson's measurement of the velocity of cathode rays and determination of the charge-to-mass ratio for the electron
- Millikan's measurement of the charge on the electron.

Forces produced by interactions between current and magnetic fields, including:

- characteristics of a magnetic field produced by a current-carrying wire
- magnitude and direction of the force acting on a current-carrying conductor in a magnetic field
- magnitude and direction of the force between two parallel current-carrying conductors
- the operation of microphones and loud speakers.

The principles and applications of DC motors and AC induction motors, including:

- production of torque on a current-carrying loop in a magnetic field
- the main parts and uses of DC motors
- operation of a DC motor, including back emf and equilibrium at constant speed
- the main parts and advantages of AC induction motors
- the operation of an AC induction motor, including eddy currents.

Production and transmission of direct current (DC) and alternating current (AC), including:

- electromagnetic induction and Lenz's law
- the main parts and operation of DC generators and AC generators
- differences between AC and DC generator outputs, including current-versus-time relationship
- inductance in transformers, including dependence on flux change, role of laminated iron core, voltage relationship between primary and secondary coils and effects of flux linkage/leakage
- application of the law of conservation of energy to an ideal transformer (power input to the primary coil equals power output from the secondary coil)

- transmission of electrical energy using AC.

Quantum theory of light, including:

- atomic emission and absorption spectra
- the hydrogen spectrum and the Balmer equation as a descriptive and predictive model
- Planck's quantum concept, which successfully modelled black body radiation measurements, avoiding the 'ultraviolet catastrophe' predicted by classical wave theory
- Hertz's observation of the photoelectric effect and its subsequent investigation by Lenard
- Einstein's explanation of photoelectric effect (a quantum idea).

Development of quantum theory, and the evidence supporting the changed ideas, including:

- strengths and limitations of the Rutherford nuclear model of the atom, which was based on the results of the Geiger–Marsden experiment
- strengths of Bohr's quantum model of the atom (which explained spectral lines and improved on the Rutherford nuclear model) and limitations of the model
- de Broglie's proposal of the existence of matter waves and its explanation of Bohr's stable orbits
- Davisson and Germer's experimental confirmation of the wave nature of electrons by scattering electrons to produce a diffraction pattern
- Schrödinger's use of the wave nature of matter to further develop the quantum model of the atom
- the importance of Heisenberg's uncertainty principle and Pauli's exclusion principle in the development of the quantum model of the atom.

Development of the laser, including:

- stimulated emission of radiation
- methods of producing a population inversion
- the amplification of light by a population inversion
- use of optical feedback in lasers
- signal amplification in optical fibres (for example, erbium-doped fibre amplifier)
- properties of laser beams, including propagation in a straight line, one optical wavelength, very small focus and very high intensity.

Particle accelerators, including:

- differences in methods of particle acceleration by cyclotrons, synchrotrons and linear accelerators
- detection of accelerator-produced particles and the conservation laws which apply
- detection of high-energy cosmic rays and their contribution to the Standard Model
- characteristics of leptons, bosons and hadrons
- production of energy from interactions between matter and antimatter.

The Standard Model, including:

- the interaction of subatomic particles in terms of three fundamental forces (electromagnetic forces, strong nuclear forces and weak nuclear forces)
- matter particles (particles with no smaller parts), including quarks and leptons
- force carrier particles (bosons, including gluons and photons) which mediate each fundamental force
- 12 fundamental particles of matter (six quarks and six leptons and their antiparticles)
- nature of quarks
- the failure of the Standard Model to account for gravity, and the search for gravitational waves and gravitons.

The relationship between the Big Bang model of the universe and the Standard Model, including:

- the Big Bang theory and the evidence that supports the theory
- the stages of the evolution of the universe proposed by different theories, including the sequencing of Big Bang Theory, the Grand Unified Theory (GUT), inflation era, hadron era, lepton era, radiation era and matter dominated era.

## Science as a human endeavour

The nature and practice of physics, including:

- the dynamic nature of the body of knowledge in physics which is subject to change as new knowledge and technologies are developed, and as the validity and reliability of underlying models, data and conclusions improve
- the role of physicists in designing new technologies (for example, high-speed maglev trains, the electron microscope, lasers, PET scan)
- the production and distribution of electricity and the operation of AC and DC motors.

Contemporary research and applications of physics, including:

- the operation of an induction cook top
- superconductors and their uses (for example, the potential for highly efficient transfer of electricity, very fast computers, magnetic resonance imaging (MRI))
- the everyday use of lasers (for example, in entertainment (DVD and laser shows); detection of pollution (light detection and ranging (LIDAR)); manufacturing (laser welding cars to maintain structural integrity and minimise weight); medicine (eye surgery))
- the construction of the Large Hadron Collider (CERN) and the quest for the Higgs boson
- the ongoing development of models and theories (for example, the Grand Unified Theory, evidence and the hunt for dark matter).

The development of ideas in physics, including:

- competing theories about the nature of cathode rays
- historical experiments and human stories related to development of models and applications in physics (for example, Ørsted's observations on movement of a compass needle near a current-carrying conductor; Faraday's experiment with motor effect and electromagnetic induction; Siemens, Edison and Westinghouse and their contributions to the commercial production of electricity; experiments with transformers)
- development of the laser through application of the understanding of the emission and absorption of photons by atoms (for example, the helium–neon laser)

- the role of particle accelerators and high-energy events in nature in testing and extending knowledge and understanding of the fundamental forces and particles of nature
- the historical experiments which have led to the evolution of atomic models and the need for new models and theories.

### Science inquiry skills

Design and perform investigations, experiments and simulations related to physical models and relationships, considering safety, methodology and ethics, including at least one extended experimental investigation involving a range of inquiry skills. Examples of possible investigations include:

- investigating different types of cathode ray tubes
- using Ørsted's law to measure the strength of Earth's magnetic field
- demonstrating the force on a moving charge in a magnetic field
- measuring the motor effect
- constructing and analysing a transformer, a DC motor, a DC generator and an AC generator
- demonstrating the principle of an AC induction motor
- demonstrating Lenz's law
- determining the wavelength of a laser pointer with diffraction of a ruler
- using a laser to demonstrate poisson's spot
- communicating sound via a laser beam
- using a modulated laser and an oscilloscope to measure the speed of light
- observing the visible spectrum of hydrogen.

Perform investigations and experiments, including:

- using physics concepts to generate questions and to guide the writing of hypotheses that inform the design of investigations
- selecting and using equipment and materials appropriate to the task (for example, hydrogen discharge tube, diffraction grating, spectrometer, spectroscope, cathode ray tubes, magnets, absorption and emission spectra of elements, hand generator, galvanometer, motor kit, laser or sodium lamp)
- accessing, critically reading and extracting information from a variety of texts, and referencing sources appropriately
- including estimate of uncertainties of data in quantitative measurements
- analysing quantitative data using mathematical and/or graphical methods
- proposing mathematical models for data (for example, linear, inverse, inverse square relationships)
- developing an understanding of the relationship between the algebraic and graphical representations of mathematical relationships in physics
- formulating explanations based on experimental evidence
- evaluating methods employed in investigations and suggest specific changes to improve the accuracy and reliability of results.

Engage in critical, creative, innovative and reflective thinking, including:

- evaluating the validity of scientific arguments, scientific investigations, measurements, procedures used, models and conclusions
- using probabilities in assessing risk (for example, lightning, effect of household DC fields, safety of lasers)
- generating ideas, plans, processes and/or products to solve problems and to challenge current thinking
- explaining the importance of uncertainty in data when testing a scientific model
- problem-solving issues relating to physics (for example, analysing and making recommendations regarding the cost/benefit of pursuing 'big' science projects like the particle accelerators or large telescopes).

Analyse and synthesise information relating to physics, including:

- evaluating claims in advertising and the media (for example, the search for the Higgs boson, 'The Theory of Everything')
- researching, selecting and synthesising relevant information from a range of sources, and referencing sources appropriately
- using and interpreting models and simulations to aid understanding and communication of physics concepts.

Communicate ideas and findings, including:

- creating and presenting structured reports of experimental and investigative work
- discussing results and findings with others to develop understanding
- using correct scientific language when describing methods, conclusions and explanations
- using correct physics representations when reporting findings (for example, drawing field lines to represent the direction and intensity of electric and magnetic fields and describing the effects of these on charges)
- sharing and exchanging information, including through ICT, in collaborative endeavours, observing social protocols, ethical use of information and information security
- explaining issues and concepts related to physics to a range of audiences.