Government of Western Australia
School Curriculum and Standards Authority

PHYSICS

ATAR COURSE

Year 12 syllabus

Content

Rationale

Physics is a fundamental science that endeavours to explain all the natural phenomena that occur in the universe. Its power lies in the use of a comparatively small number of assumptions, models, laws and theories to explain a wide range of phenomena, from the incredibly small to the incredibly large. Physics has helped to unlock the mysteries of the universe and provides the foundation of understanding upon which modern technologies and all other sciences are based.

The Physics ATAR course uses qualitative and quantitative models and theories based on physical laws to visualise, explain and predict physical phenomena. Models, laws and theories are developed from, and their predictions are tested by, making observations and quantitative measurements. In this course, students gather, analyse and interpret primary and secondary data to investigate a range of phenomena and technologies using some of the most important models, laws and theories of physics, including the kinetic particle model, the atomic model, electromagnetic theory, and the laws of classical mechanics.

Students investigate how the unifying concept of energy explains diverse phenomena and provides a powerful tool for analysing how systems interact throughout the universe on multiple scales. Students learn how more sophisticated theories, including quantum theory, the theory of relativity and the Standard Model, are needed to explain more complex phenomena, and how new observations can lead to models and theories being refined and developed.

Students learn how an understanding of physics is central to the identification of, and solutions to, some of the key issues facing an increasingly globalised society. They consider how physics contributes to diverse areas in contemporary life, such as engineering, renewable energy generation, communication, development of new materials, transport and vehicle safety, medical science, an understanding of climate change, and the exploration of the universe.

Studying senior secondary science provides students with a suite of skills and understandings that are valuable to a wide range of further study pathways and careers. Studying physics will enable students to become citizens who are better informed about the world around them and who have the critical skills to evaluate and make evidence-based decisions about current scientific issues. The Physics ATAR course will also provide a foundation in physics knowledge, understanding and skills for those students who wish to pursue tertiary study in science, engineering, medicine and technology.

Aims

The Physics ATAR course aims to develop students':

- appreciation of the wonder of physics and the significant contribution physics has made to contemporary society
- understanding that diverse natural phenomena may be explained, analysed and predicted using concepts, models and theories that provide a reliable basis for action
- understanding of the ways in which matter and energy interact in physical systems across a range of scales
- understanding of the ways in which models and theories are refined and new models and theories are developed in physics; and how physics knowledge is used in a wide range of contexts and informs personal, local and global issues
- investigative skills, including the design and conduct of investigations to explore phenomena and solve problems, the collection and analysis of qualitative and quantitative data, and the interpretation of evidence
- ability to use accurate and precise measurement, valid and reliable evidence, and scepticism and intellectual rigour to evaluate claims
- ability to communicate physics understanding, findings, arguments and conclusions using appropriate representations, modes and genres.

Organisation

This course is organised into a Year 11 syllabus and a Year 12 syllabus. The cognitive complexity of the syllabus content increases from Year 11 to Year 12.

Structure of the syllabus

The Year 12 syllabus is divided into two units which are delivered as a pair. The notional time for the pair of units is 110 class contact hours.

Unit 3 – Gravity and electromagnetism

Students investigate models of motion in gravitational, electric and magnetic fields to explain how forces act at a distance.

Unit 4 – Revolutions in modern physics

Students use the theory of electromagnetism to explain the production and propagation of electromagnetic waves and investigate how shortcomings in existing theories led to the development of the quantum theory of light and matter, the Special Theory of Relativity, and the Standard Model of particle physics.

Each unit includes:

- a unit description – a short description of the focus of the unit
- learning outcomes – a set of statements describing the learning expected as a result of studying the unit
- unit content – the content to be taught and learned.

Organisation of content

Science strand descriptions

The Physics ATAR course has three interrelated strands: Science Inquiry Skills, Science as a Human Endeavour and Science Understanding, which build on students' learning in the Year 7–10 Science curriculum. The three strands of the Physics ATAR course should be taught in an integrated way. The content descriptions for Science Inquiry Skills, Science as a Human Endeavour and Science Understanding have been written so that this integration is possible in each unit.

Science Inquiry Skills

Science inquiry involves identifying and posing questions; planning, conducting and reflecting on investigations; processing, analysing and interpreting data; and communicating findings. This strand is concerned with evaluating claims, investigating ideas, solving problems, reasoning, drawing valid conclusions, and developing evidence-based arguments.

Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem. Investigations can involve a range of activities, including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations.

In science investigations, the collection and analysis of data to provide evidence plays a major role. This can involve collecting or extracting information and reorganising data in the form of tables, graphs, flow charts, diagrams, text, keys, spreadsheets and databases. The analysis of data to identify and select evidence, and the communication of findings, involve the selection, construction and use of specific representations, including mathematical relationships, symbols and diagrams.

Science as a Human Endeavour

Through science, we seek to improve our understanding and explanations of the natural world. The Science as a Human Endeavour strand highlights the development of science as a unique way of knowing and doing, and explores the use and influence of science in society.

As science involves the construction of explanations based on evidence, the development of science concepts, models and theories is dynamic and involves critique and uncertainty. Science concepts, models and theories are reviewed as their predictions and explanations are continually re-assessed through new evidence, often through the application of new technologies. This review process involves a diverse range of scientists working within an increasingly global community of practice and can involve the use of international conventions and activities, such as peer review.

The use and influence of science are shaped by interactions between science and a wide range of social, economic, ethical and cultural factors. The application of science may provide great benefits to individuals, the community and the environment, but may also pose risks and have unintended consequences. As a result, decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of stakeholder needs and values. As an ever-evolving body of knowledge, science frequently informs public debate, but is not always able to provide definitive answers.

Science Understanding

Science understanding is evident when a person selects and integrates appropriate science concepts, models and theories to explain and predict phenomena, and applies those concepts, models and theories to new situations. Models in science can include diagrams, physical replicas, mathematical representations, word-based analogies (including laws and principles) and computer simulations. Development of models involves selection of the aspects of the system(s) to be included in the model, and thus models have inherent approximations, assumptions and limitations.

The Science Understanding content in each unit develops students' understanding of the key concepts, models and theories that underpin the course, and of the strengths and limitations of different models and theories for explaining and predicting complex phenomena.

Safety

Science learning experiences may involve the use of potentially hazardous substances and/or 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 and that school practices meet the requirements of the *Work Health and Safety Act 2011,* in addition to relevant State health and safety guidelines.

Animal ethics

Through a consideration of research ethics as part of Science Inquiry Skills, students will examine their own ethical position, draw on ethical perspectives when designing investigation methods, and ensure that any activities that impact on living organisms comply with the *Australian code of practice for the care and use of animals for scientific purposes 8th edition 2013* (https://www.nhmrc.gov.au/about-us/publications/australian-code-care-and-use-animals-scientific-purposes).

Any teaching activities that involve the care and use of, or interaction with, animals must comply with the *Australian code of practice for the care and use of animals for scientific purposes 8th edition 2013*, in addition to relevant State guidelines.

Mathematical skills expected of students studying the Physics ATAR course

The Physics ATAR course requires students to use the mathematical skills they have developed through the Year 7–10 Mathematics curriculum, in addition to the numeracy skills they have developed through the Science Inquiry Skills strand of the Science curriculum.

Within the Science Inquiry Skills strand, students are required to gather, represent and analyse numerical data to identify the evidence that forms the basis of their scientific arguments, claims or conclusions. In gathering and recording numerical data, students are required to make measurements with an appropriate degree of accuracy and to represent measurements using appropriate units.

Students may need to be taught inverse and inverse square relationships as they are important in physics, but are not part of the Year 10 Mathematics curriculum.

Students may need to be taught to recognise when it is appropriate to join points on a graph and when it is appropriate to use a line of best fit. They may need to be taught how to construct a straight line that will serve as the line of best fit for a set of data presented graphically.

It is assumed that students will be able to:

- perform calculations involving addition, subtraction, multiplication and division of quantities
- perform approximate evaluations of numerical expressions
- express fractions as percentages, and percentages as fractions
- calculate percentages
- recognise and use ratios
- transform decimal notation to power of ten notation
- change the subject of a simple equation
- substitute physical quantities into an equation using consistent units so as to calculate one quantity and check the dimensional consistency of such calculations
- solve simple algebraic equations
- comprehend and use the symbols/notations $<$, $>$, Δ, $\approx$, $\surd$, $\leq$, $\geq$, $\sum$
- translate information between graphical, numerical and algebraic forms

- distinguish between discrete and continuous data and then select appropriate forms, variables and scales for constructing graphs
- interpret frequency tables and diagrams, pie charts and histograms
- describe and compare data sets using range, mean and median
- interpret the slope of a linear graph
- use Pythagoras' theorem, similarity of triangles and the angle sum of a triangle
- solve simple sine, cosine and tangent relationships in a right angle triangle
- recognise the graphical representation of a sine curve.

Representation of the general capabilities

The general capabilities encompass the knowledge, skills, behaviours and dispositions that will assist students to live and work successfully in the twenty-first century. Teachers may find opportunities to incorporate the capabilities into the teaching and learning program for the Physics ATAR course. The general capabilities are not assessed unless they are identified within the specified unit content.

Literacy

Literacy is important in students' development of Science Inquiry Skills and their understanding of content presented through the Science Understanding and Science as a Human Endeavour strands. Students gather, interpret, synthesise and critically analyse information presented in a wide range of genres, modes and representations (including text, flow diagrams, symbols, graphs and tables). They evaluate information sources and compare and contrast ideas, information and opinions presented within and between texts. They communicate processes and ideas logically and fluently and structure evidence-based arguments, selecting genres and employing appropriate structures and features to communicate for specific purposes and audiences.

Numeracy

Numeracy is key to students' ability to apply a wide range of Science Inquiry Skills, including making and recording observations; ordering, representing and analysing data; and interpreting trends and relationships. They employ numeracy skills to interpret complex spatial and graphic representations, and to appreciate the ways in which physical systems are structured, interact and change across spatial scales. They engage in analysis of data, including issues relating to reliability and probability, and they interpret and manipulate mathematical relationships to calculate and predict values.

Information and communication technology capability

Information and communication technology (ICT) capability is a key part of Science Inquiry Skills. Students use a range of strategies to locate, access and evaluate information from multiple digital sources; to collect, analyse and represent data; to model and interpret concepts and relationships; and to communicate and share science ideas, processes and information. Through exploration of Science as a Human Endeavour concepts, students assess the impact of ICT on the development of science and the application of science in society, particularly with regard to collating, storing, managing and analysing large data sets.

Critical and creative thinking

Critical and creative thinking is particularly important in the science inquiry process. Science inquiry requires the ability to construct, review and revise questions and hypotheses about increasingly complex and abstract scenarios and to design related investigation methods. Students interpret and evaluate data; interrogate, select and cross-reference evidence; and analyse processes, interpretations, conclusions and claims for validity and reliability, including reflecting on their own processes and conclusions. Science is a creative endeavour and students devise innovative solutions to problems, predict possibilities, envisage consequences and speculate on possible outcomes as they develop Science Understanding and Science Inquiry Skills. They also appreciate the role of critical and creative individuals and the central importance of critique and review in the development and innovative application of science.

Personal and social capability

Personal and social capability is integral to a wide range of activities in the Physics ATAR course, as students develop and practise skills of communication, teamwork, decision-making, initiative-taking and self-discipline with increasing confidence and sophistication. In particular, students develop skills in both independent and collaborative investigation; they employ self-management skills to plan effectively, follow procedures efficiently and work safely; and they use collaboration skills to conduct investigations, share research and discuss ideas. In considering aspects of Science as a Human Endeavour, students also recognise the role of their own beliefs and attitudes in their response to science issues and applications, consider the perspectives of others, and gauge how science can affect people's lives.

Ethical understanding

Ethical understanding is a vital part of science inquiry. Students evaluate the ethics of experimental science, codes of practice, and the use of scientific information and science applications. They explore what integrity means in science, and they understand, critically analyse and apply ethical guidelines in their investigations. They consider the implications of their investigations on others, the environment and living organisms. They use scientific information to evaluate the claims and actions of others and to inform ethical decisions about a range of social, environmental and personal issues and applications of science.

Intercultural understanding

Intercultural understanding is fundamental to understanding aspects of Science as a Human Endeavour, as students appreciate the contributions of diverse cultures to developing science understanding and the challenges of working in culturally diverse collaborations. They develop awareness that raising some debates within culturally diverse groups requires cultural sensitivity, and they demonstrate open-mindedness to the positions of others. Students also develop an understanding that cultural factors affect the ways in which science influences and is influenced by society.

Representation of the cross-curriculum priorities

The cross-curriculum priorities address contemporary issues which students face in a globalised world. Teachers may find opportunities to incorporate the priorities into the teaching and learning program for the Physics ATAR course. The cross-curriculum priorities are not assessed unless they are identified within the specified unit content.

Aboriginal and Torres Strait Islander histories and cultures

Contexts that draw on Aboriginal and Torres Strait Islander histories and cultures provide an opportunity for students to appreciate Aboriginal and Torres Strait Islander Peoples' understanding of physical phenomena, including the motion of objects, and astronomical phenomena, including Aboriginal constellations, their meanings and relationship with Creation/Dreaming stories.

Asia and Australia's engagement with Asia

Contexts that draw on Asian scientific research and development and collaborative endeavours in the Asia Pacific region provide an opportunity for students to investigate Asia and Australia's engagement with Asia. Students could examine the important role played by people of the Asia region in such areas as medicine, communication technologies, transportation, sports science and energy security. They could consider collaborative projects between Australian and Asian scientists and the contribution these make to scientific knowledge.

Sustainability

The cross-curriculum priority of Sustainability provides authentic contexts for exploring, investigating and understanding the function and interactions of physical systems. The Physics ATAR course explores a wide range of physical systems that operate at different temporal and spatial scales. By investigating the relationships between systems and system components and how systems respond to change, students develop an appreciation for the ways in which matter and energy interactions shape the Earth system. In exploring applications of physics knowledge, students appreciate that science provides the basis for decision-making in many areas of society and that these decisions can impact on the Earth system. They understand the importance of using physical science knowledge to predict possible effects of human and other activity, and to develop management plans or alternative technologies that minimise these effects and provide for a more sustainable future.

Unit 3 – Gravity and electromagnetism

Unit description

Field theories have enabled physicists to explain a vast array of natural phenomena and have contributed to the development of technologies that have changed the world, including electrical power generation and distribution systems, artificial satellites and modern communication systems. In this unit, students develop a deeper understanding of motion and its causes by using Newton's Laws of Motion and the gravitational field model to analyse motion on inclined planes, the motion of projectiles, and satellite motion. They investigate electromagnetic interactions and apply this knowledge to understand the operation of direct current motors, direct current (DC) and alternating current (AC) generators, transformers, and AC power distribution systems. Students also investigate the production of electromagnetic waves.

Contexts that can be investigated in this unit include technologies, such as artificial satellites, navigation devices, large-scale power generation and distribution, motors and generators, electric cars, synchrotron science, medical imaging, and related areas of science and engineering, such as sports science, amusement parks, ballistics and forensics.

Through the investigation of appropriate contexts, students explore the ways in which models and theories related to gravity and electromagnetism, and associated technologies, have developed over time and through interactions with social, economic, cultural and ethical considerations. They investigate the ways in which science contributes to contemporary debate about local, regional and international issues, including evaluation of risk and action for sustainability, and recognise the limitations of science to provide definitive answers in different contexts.

Students develop their understanding of field theories of gravity and electromagnetism through investigations of motion and electromagnetic phenomena. Through these investigations, they develop skills in relating graphical representations of data to quantitative relationships between variables, using lines of force to represent vector fields, and interpreting interactions in two and three dimensions. They continue to develop skills in planning, conducting and interpreting the results of primary and secondary investigations and in evaluating the validity of primary and secondary data.

Learning outcomes

By the end of this unit, students:

- understand that motion in gravitational, electric and magnetic fields can be explained using Newton's Laws of Motion
- understand how the electromagnetic wave model explains the production and propagation of electromagnetic waves across the electromagnetic spectrum
- understand transformations and transfer of energy in electromagnetic devices, as well as transformations and transfer of energy associated with motion in gravitational, electric and magnetic fields
- understand how models and theories have developed over time, and the ways in which physical science knowledge and associated technologies interact with social, economic, cultural and ethical considerations

- use science inquiry skills to design, conduct, analyse and evaluate investigations into uniform circular motion, projectile motion, satellite motion and gravitational and electromagnetic phenomena, and to communicate methods and findings
- use algebraic and graphical representations to calculate, analyse and predict measurable quantities related to motion, gravitational effects and electromagnetic phenomena
- evaluate, with reference to evidence, claims about motion, gravity and electromagnetic phenomena and associated technologies, and justify evaluations
- communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.

Unit content

An understanding of the Year 11 content is assumed knowledge for students in Year 12. It is recommended that students studying Unit 3 and Unit 4 have completed Unit 1 and Unit 2.

This unit includes the knowledge, understandings and skills described below. This is the examinable content.

Science Inquiry Skills

- identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes
- design investigations, including the procedure to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics
- conduct investigations, including the manipulation of force measurers and electromagnetic devices, safely, competently and methodically for the collection of valid and reliable data
- represent data in meaningful and useful ways, including using appropriate Système Internationale (SI) units, symbols, and significant figures; organise and analyse data to identify trends, patterns and relationships; identify sources of uncertainty and techniques to minimise these uncertainties; utilise uncertainty and percentage uncertainty to determine the uncertainty in the result of simple calculations, and evaluate the impact of measurement uncertainty on experimental results; and select, synthesise and use evidence to make and justify conclusions
- interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the accuracy and precision of available evidence; and use reasoning to construct scientific arguments
- select, construct and use appropriate representations, including text and graphic representations of empirical and theoretical relationships, vector diagrams, free body/force diagrams, field diagrams and circuit diagrams, to communicate conceptual understanding, solve problems and make predictions
- select, use and interpret appropriate mathematical representations, including linear and non-linear graphs and algebraic relationships representing physical systems, to solve problems and make predictions
- communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports

Science as a Human Endeavour

Gravity and motion

Artificial satellites are used for communication, navigation, remote-sensing and research. Their orbits and uses are classified by altitude (low, medium or high Earth orbits) and by inclination (equatorial, polar and sun-synchronous orbits). Communication via satellite is now used for global positioning systems (GPS), satellite phones and television. Navigation services support management and monitoring of traffic and aircraft movement. Geographic information science uses data from satellites to monitor population movement, biodiversity and ocean currents.

Science Understanding

Gravity and motion

- the movement of free-falling bodies in Earth's gravitational field is predictable
- all objects with mass attract one another with a gravitational force; the magnitude of this force can be calculated using Newton's Law of Universal Gravitation

  This includes applying the relationship:

  $$F_g = G\frac{m_1 m_2}{r^2}$$

- objects with mass produce a gravitational field in the space that surrounds them; field theory attributes the gravitational force on an object to the presence of a gravitational field

  This includes applying the relationship:

  $$F_{weight} = m\,g$$

- when a mass moves or is moved from one point to another in a gravitational field and its potential energy changes, work is done on the mass by the field

  This includes applying the relationships:

  $$E_{\mathrm{p}} = m\,g\,\Delta h\,, \qquad W = F\,s\,, \qquad W = \Delta E\,, \qquad E_{\mathrm{k}} = \tfrac{1}{2} m\,v^2$$

- gravitational field strength is defined as the net force per unit mass at a particular point in the field

  This includes applying the relationships:

  $$g = \frac{F_g}{m} = G\frac{M}{r^2}$$

- the vector nature of the gravitational force can be used to analyse motion on inclined planes by considering the components of the gravitational force (that is, weight) parallel and perpendicular to the plane
- projectile motion can be analysed quantitatively by treating the horizontal and vertical components of the motion independently

This includes applying the relationships:

$$v_{av} = \frac{s}{t}, \qquad a = \frac{v - u}{t}, \quad v = u + at, \quad s = ut + \tfrac{1}{2}at^2, \quad v^2 = u^2 + 2as, \quad E_k = \tfrac{1}{2}mv^2$$

- when an object experiences a net force of constant magnitude perpendicular to its velocity, it will undergo uniform circular motion, including circular motion on a horizontal plane and around a banked track; and vertical circular motion

  This includes applying the relationships:

  $$v = \frac{2\pi r}{T}, \qquad a_c = \frac{v^2}{r}, \qquad \text{resultant } F_c = ma_c = \frac{mv^2}{r}$$

- Newton's Law of Universal Gravitation is used to explain Kepler's laws of planetary motion and to describe the motion of planets and other satellites, modelled as uniform circular motion

  This includes deriving and applying the relationship:

  $$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$$

- when an object experiences a net force at a distance from a pivot and at an angle to the lever arm, it will experience a torque or moment about that point

  This includes applying the relationship:

  $$\tau = r\,F\sin\theta$$

- for a rigid body to be in equilibrium, the sum of the forces and the sum of the moments must be zero

  This includes applying the relationships:

  $$\sum F = 0, \qquad \tau = r\,F\sin\theta, \qquad \sum \tau = 0$$

Science as a Human Endeavour

Electromagnetism

Electromagnetism is utilised in a range of technological applications, including:

- DC electric motor with commutator, and back emf
- AC and DC generators
- transformers
- regenerative braking
- induction hotplates
- large scale AC power distribution systems.

Science Understanding

Electromagnetism

- electrostatically charged objects exert a force upon one another; the magnitude of this force can be calculated using Coulomb's Law

  This includes applying the relationship:

  $$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$

- point charges and charged objects produce an electric field in the space that surrounds them; field theory attributes the electrostatic force on a point charge or charged body to the presence of an electric field
- a positively charged body placed in an electric field will experience a force in the direction of the field; the strength of the electric field is defined as the force per unit charge

  This includes applying the relationship:

  $$E = \frac{F}{q} = \frac{V}{d}$$

- when a charged body moves or is moved from one point to another in an electric field and its potential energy changes, work is done on the charge by the field

  This includes applying the relationship:

  $$V = \frac{W}{q}$$

- the direction of conventional current is that in which the flow of positive charges takes place, while the electron flow is in the opposite direction
- current-carrying wires are surrounded by magnetic fields; these fields are utilised in solenoids and electromagnets
- the strength of the magnetic field produced by a current is a measure of the magnetic flux density

  This includes applying the relationship:

  $$B = \frac{\mu_0}{2\pi} \frac{I}{r}$$

- magnets, magnetic materials, moving charges and current-carrying wires experience a force in a magnetic field when they cut flux lines; this force is utilised in DC electric motors and particle accelerators

  This includes applying the relationships:

  $F = q\,v\,B$ where $v \perp B$, $\quad F = I\,\ell\,B$ where $\ell \perp B$

- the force due to a current in a magnetic field in a DC electric motor produces a torque on the coil in the motor

  This includes applying the relationship:

  $$\tau = r_{\perp} F$$

- an induced emf is produced by the relative motion of a straight conductor in a magnetic field when the conductor cuts flux lines

  This includes applying the relationship:

  $$\text{induced emf} = \ell v B \quad \text{where } v \perp B$$

- magnetic flux is defined in terms of magnetic flux density and area

  This includes applying the relationship:

  $$\Phi = B A_{\perp}$$

- a changing magnetic flux induces a potential difference; this process of electromagnetic induction is used in step-up and step-down transformers, DC and AC generators

  This includes applying the relationships:

  $$\text{induced emf} = -N \frac{(\Phi_2 - \Phi_1)}{t} = -N \frac{\Delta\Phi}{t} = -N \frac{\Delta(B A_{\perp})}{t}$$

  $$\text{AC generator emf}_{\text{max}} = 2N\ell vB = 2\pi NBA_{\perp}f \,, \quad \text{emf}_{\text{rms}} = \frac{emf_{max}}{\sqrt{2}}$$

  $$\frac{V_{\text{p}}}{V_{\text{s}}} = \frac{N_{\text{p}}}{N_{\text{s}}}$$

  $$P = V I = I^2 R = \frac{V^2}{R}$$

- conservation of energy, expressed as Lenz's Law of electromagnetic induction, is used to determine the direction of induced current

Unit 4 – Revolutions in modern physics

Unit description

The development of quantum theory and the theory of relativity fundamentally changed our understanding of how nature operates and led to the development of a wide range of new technologies, including technologies that revolutionised the storage, processing and communication of information. In this unit, students examine observations of relative motion, light and matter that could not be explained by existing theories, and investigate how the shortcomings of existing theories led to the development of the special theory of relativity and the quantum theory of light and matter. Students evaluate the contribution of the quantum theory of light to the development of the quantum theory of the atom, and examine the Standard Model of particle physics and the Big Bang theory.

Contexts that can be investigated in this unit include technologies, such as photo radar, fibre optics, DVDs, GPS navigation, lasers, modern electric lighting, medical imaging, nanotechnology, semiconductors, quantum computers and particle accelerators, and astronomical telescopes, such as the Square Kilometre Array. Other contexts may include black holes, dark matter, and related areas of science, such as space travel and the digital revolution.

Through the investigation of appropriate contexts, students explore the ways in which these models and theories, and associated technologies, have developed over time and through interactions with social, economic, cultural and ethical considerations. They investigate the ways in which science contributes to contemporary debate about local, regional and international issues, including evaluation of risk and action for sustainability, and they recognise the limitations of science to provide definitive answers in different contexts.

Through investigation, students apply their understanding of relativity, black body radiation, wave/particle duality, and the quantum theory of the atom, to make and/or explain observations of a range of phenomena, such as atomic emission and absorption spectra, the photoelectric effect, lasers, and Earth's energy balance. They continue to develop skills in planning, conducting and interpreting the results of investigations, in synthesising evidence to support conclusions, and in recognising and defining the realm of validity of physical theories and models.

Learning outcomes

By the end of this unit, students:

- understand the consequences for space and time of the equivalence principle for inertial frames of reference
- understand how the quantum theory of light and matter explains black body radiation, the photoelectric effect, and atomic emission and absorption spectra
- use the Standard Model to describe the nature of and interaction between the fundamental particles that form the building blocks of matter
- understand how models and theories have developed over time, and the ways in which physical science knowledge and associated technologies interact with social, economic, cultural and ethical considerations

- use science inquiry skills to design, conduct, analyse and evaluate investigations into frames of reference, diffraction, black body and atomic emission spectra, the photoelectric effect, and photonic devices, and to communicate methods and findings
- use algebraic and graphical models to solve problems and make predictions related to the theory and applications of special relativity and quantum theory
- evaluate the experimental evidence that supports the theory of relativity, wave-particle duality, the Bohr model of the atom, the Standard Model, and the Big Bang theory
- communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.

Unit content

This unit builds on the content covered in Unit 3.

This unit includes the knowledge, understandings and skills described below. This is the examinable content.

Science Inquiry Skills

- identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes
- design investigations, including the procedure to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics
- conduct investigations, including use of simulations and manipulation of spectral devices, safely, competently and methodically for the collection of valid and reliable data
- represent data in meaningful and useful ways, including using appropriate Système Internationale (SI) units, symbols, and significant figures; organise and analyse data to identify trends, patterns and relationships; identify sources of uncertainty and techniques to minimise these uncertainties; utilise uncertainty and percentage uncertainty to determine the cumulative uncertainty resulting from simple calculations, and evaluate the impact of measurement uncertainty on experimental results; and select, synthesise and use evidence to make and justify conclusions
- interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments
- select, construct and use appropriate representations, including text and graphic representations of empirical and theoretical relationships, simulations and atomic energy level diagrams, to communicate conceptual understanding, solve problems and make predictions
- select, use and interpret appropriate mathematical representations, including linear and non-linear graphs and algebraic relationships representing physical systems, to solve problems and make predictions
- communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports

Science as a Human Endeavour

Wave particle duality and the quantum theory

Models that were initially rejected can be revisited as more evidence becomes available. For many years, the presence of the luminiferous ether was proposed as the medium by which light is propagated. Around 1800, Thomas Young showed through experimentation that light passing through a double slit showed interference and thus wave properties. The wave explanation of Young's double slit demonstration was initially rejected until other physicists, including Fresnel and Poisson, showed that light was able to undergo diffraction, a property of waves. Later, in the 1860s, James Clerk Maxwell developed a theory of electromagnetism and showed that electromagnetic waves would travel through space at the speed of light, implying light was an electromagnetic wave.

The use of devices developed from the application of quantum physics, including the laser and photovoltaic cells, have significantly changed many aspects of society.

Science Understanding

Wave particle duality and the quantum theory

- light exhibits many wave properties; however, it cannot only be modelled as a mechanical wave because it can travel through a vacuum
- a wave model explains a wide range of light-related phenomena, including reflection, refraction, dispersion, diffraction and interference, such as in Young's double-slit experiment. A transverse wave model is required to explain polarisation
- electromagnetic waves are transverse waves made up of mutually perpendicular, oscillating electric and magnetic fields
- oscillating charges produce electromagnetic waves of the same frequency as the oscillation; electromagnetic waves cause charges to oscillate at the frequency of the wave
- atomic phenomena and the interaction of light with matter indicate that states of matter and energy are quantised into discrete values
- on the atomic level, electromagnetic radiation is emitted or absorbed in discrete packets called photons. The energy of a photon is proportional to its frequency. The constant of proportionality, Planck's constant, can be determined experimentally using the photoelectric effect and the threshold voltage of coloured LEDs

  This includes applying the relationships:

  $c = f\lambda \qquad E = hf = \frac{hc}{\lambda} \qquad E_k = h\,f - W$
- black body radiation and the photoelectric effect are explained using the concept of light quanta
- atoms of an element emit and absorb specific wavelengths of light that are unique to that element; this is the basis of spectral analysis

  This includes applying the relationships:

  $\Delta E = hf \qquad E_2 - E_1 = hf$

- the Bohr model of the hydrogen atom integrates light quanta and atomic energy and states to explain the specific wavelengths in the hydrogen spectrum and in the spectra of other simple atoms; this model enables line spectra to be correlated with atomic energy-level diagrams and explains the phenomenon of fluorescence and phosphorescence
- on the atomic level, energy and matter exhibit the characteristics of both waves and particles. Young's double slit experiment is explained with a wave model but produces the same interference and diffraction patterns when one photon at a time or one electron at a time are passed through the slits

  This includes applying the relationship:

  $$\lambda = \frac{h}{p}$$

Science as a Human Endeavour

Special relativity

Research studies of cosmic rays show that interactions between cosmic rays and the upper atmosphere produce muons. These particles have a lifetime of about two microseconds and should have ceased to exist before reaching the surface of the Earth. However, because they are travelling near the speed of light, the time dilation effect allows them to complete their journey. Continuing research in the field of high-energy physics is important for improving our understanding of our world and its origins.

Science Understanding

Special relativity

- observations of objects travelling at very high speeds cannot be explained by Newtonian physics. These include the dilated half-life of high-speed muons created in the upper atmosphere, and the momentum of high-speed particles in particle accelerators
- Einstein's special theory of relativity predicts significantly different results to those of Newtonian physics for velocities approaching the speed of light
- the special theory of relativity is based on two postulates: that the speed of light in a vacuum is an absolute constant, and that all inertial reference frames are equivalent
- motion can only be measured relative to an observer; length and time are relative quantities that depend on the observer's frame of reference

  This includes applying the relationships:

  $$\ell = \ell_0 \sqrt{\left(1 - \frac{v^2}{c^2}\right)} \qquad t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}} \qquad u = \frac{v + u'}{1 + \frac{v\,u'}{c^2}} \qquad u' = \frac{u - v}{1 - \frac{u\,v}{c^2}}$$

- relativistic momentum increases at high relative speed and prevents an object from reaching the speed of light

  This includes applying the relationship:

$$p_v = \frac{m\,v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

- the concept of mass-energy equivalence emerged from the special theory of relativity and explains the source of the energy produced in nuclear reactions. The mass of an object is constant and independent of its motion

  This includes applying the relationship:

$$E_t = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

- The total energy of a moving object is the sum of the energy due to its mass at rest and kinetic energy

  This includes applying the relationships:

$$E_{rest} = mc^2 \qquad E_t = E_k + E_{rest}$$

Science as a Human Endeavour

The Standard Model

The Big Bang theory describes the early development of the universe, including the formation of subatomic particles from energy and the subsequent formation of atomic nuclei. There is a variety of evidence that supports the Big Bang theory, including Cosmic Background Radiation, the abundance of light elements and the red shift of light from galaxies that obey Hubble’s Law. Alternative theories exist, including the Steady State theory, but the Big Bang theory is the most widely accepted theory today.

Science Understanding

The Standard Model

- the Big Bang theory explains the expansion of space, which is measured by redshift and is supported by Hubble’s law

  This includes applying the relationship:

$$v = H_0 d$$

- the Standard Model is used to describe the evolution of forces and the creation of matter in the Big Bang theory

- high-energy particle accelerators use electric and magnetic fields to accelerate particles

  This includes deriving, understanding and applying the relationship:

  $$\frac{m\,v^2}{r} = q\,v\,B$$

- mass-energy equivalence and the motion of high energy particles in accelerators can be used to test theories of particle physics, including the Standard Model
- baryons and mesons are hadrons, which are composite particles made up of quarks
- the Standard Model is based on the premise that all matter in the universe is made up from elementary matter particles called quarks and leptons and their corresponding antiparticles. Fundamental particles interact via the four fundamental forces
- the Standard Model explains three of the four fundamental forces (strong, weak and electromagnetic forces) in terms of an exchange of force-carrying particles called gauge bosons; each force is mediated by a different type of gauge boson
- lepton number, baryon number and electric charge are quantities that are conserved in all interactions between particles; these conservation laws can be used to support or invalidate proposed reactions

School-based assessment

The Western Australian Certificate of Education (WACE) Manual contains essential information on principles, policies and procedures for school-based assessment that needs to be read in conjunction with this syllabus.

Teachers design school-based assessment tasks to meet the needs of students. The table below provides details of the assessment types for the Physics ATAR Year 12 syllabus and the weighting for each assessment type.

Assessment table – Year 12

Type of assessment	Weighting
Science Inquiry There must be at least one experiment, one investigation and one evaluation and analysis completed in this pair of units. Appropriate strategies should be used to authenticate student achievement on an out-of-class assessment task. **Experiment** Practical tasks designed to develop or assess a range of laboratory related skills and conceptual understanding of physics principles, and skills associated with representing data; organising and analysing data to identify trends and relationships; recognising error, uncertainty and limitations in data; and selecting, synthesising and using evidence to construct and justify conclusions. Tasks can take the form of practical skills tasks, laboratory reports and short in-class tests to validate the knowledge gained. **Investigation** Activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem. Investigations can involve experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations. Assessment tasks can take the form of an experimental design brief, a formal investigation report requiring qualitative and/or quantitative analysis of the data and evaluation of physical information, or exercises requiring qualitative and/or quantitative analysis of second-hand data. **Evaluation and analysis** Involves interpreting a range of scientific and media texts; evaluating processes, claims and conclusions by considering the accuracy and precision of available evidence; and using reasoning to construct scientific arguments. Assessment tasks can take the form of answers to specific questions based on individual research; exercises requiring analysis; and interpretation and evaluation of physics information in scientific and media texts.	20%
Test Tests typically consist of questions requiring short answers, extended answers and problem-solving. This assessment type is conducted in supervised classroom settings.	30%
Examination Examinations require students to demonstrate use of terminology, understanding and application of concepts and knowledge of factual information. It is expected that questions would allow students to respond at their highest level of understanding. Typically conducted at the end of each semester and/or unit and reflecting the examination design brief for this syllabus. This assessment type is conducted in supervised classroom settings.	50%

Teachers are required to use the assessment table to develop an assessment outline for the pair of units.

The assessment outline must:

- include a set of assessment tasks
- include a general description of each task
- indicate the unit content to be assessed
- indicate a weighting for each task and each assessment type
- include the approximate timing of each task (for example, the week the task is conducted, or the issue and submission dates for an extended task).

In the assessment outline for the pair of units, each assessment type must be included at least twice, except in Science Inquiry, which must be included at least once.

The set of assessment tasks must provide a representative sampling of the content for Unit 3 and Unit 4.

Assessment tasks not administered under test/controlled conditions require appropriate validation/authentication processes.

Grading

Schools report student achievement in terms of the following grades:

Grade	Interpretation
A	Excellent achievement
B	High achievement
C	Satisfactory achievement
D	Limited achievement
E	Very low achievement

The teacher prepares a ranked list and assigns the student a grade for the pair of units. The grade is based on the student's overall performance as judged by reference to a set of pre-determined standards. These standards are defined by grade descriptions and annotated work samples. The grade descriptions for the Physics ATAR Year 12 syllabus are provided in Appendix 1. They can also be accessed, together with annotated work samples, through the Guide to Grades link on the course page of the Authority website at www.scsa.wa.edu.au.

To be assigned a grade, a student must have had the opportunity to complete the education program, including the assessment program (unless the school accepts that there are exceptional and justifiable circumstances).

Refer to the WACE Manual for further information about the use of a ranked list in the process of assigning grades.

ATAR course examination

All students enrolled in the Physics ATAR Year 12 course are required to sit the ATAR course examination. The examination is based on a representative sampling of the content for Unit 3 and Unit 4. Details of the ATAR course examination are prescribed in the examination design brief below.

Refer to the WACE Manual for further information.

Examination design brief – Year 12

Time allowed
Reading time before commencing work: ten minutes
Working time for paper: three hours

Permissible items
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters
Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination, drawing templates, drawing compass and a protractor

Provided by the supervisor
A Formulae and Data booklet

Additional information
Instructions to the candidate state:
When calculating numerical answers, show your working or reasoning clearly. Give final answers to three significant figures and include appropriate units where applicable.
When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

Section	Supporting information
Section One **Short response** 30% of the total examination 10–15 questions Suggested working time: 50 minutes	Questions are generally single-step. Responses can include diagrams, tables, calculations, estimations, explanations, and/or predictions.
Section Two **Problem-solving** 50% of the total examination 6–8 questions Suggested working time: 90 minutes	Questions can be scaffolded, and require the candidate to respond to stimulus material. Stimulus material can include scenarios, current events information, extracts from scientific journals, and/or any other data. Responses can include diagrams, tables, calculations, estimations, explanations, and/or predictions.
Section Three **Comprehension** 20% of the total examination Two questions Suggested working time: 40 minutes	Questions can include unfamiliar contexts, requiring candidates to apply concepts, principles and strategies to solve problems. Calculations can be required. Each question can relate to a written or graphical stimulus of up to two pages. Stimulus material can include scenarios, current events information, extracts from scientific journals, and/or any other data. The questions can have sequential parts.

Appendix 1 – Grade descriptions Year 12

A	**Understanding and applying concepts** Applies models and scientific principles to comprehensively explain and link complex systems and processes. Supports responses with a range of appropriate examples and accurate diagrams. Consistently applies scientific knowledge to accurately explain, in detail, unfamiliar contexts or examples. Selects and accurately evaluates scientific information from a variety of sources to present logical, well-developed arguments, which are supported by relevant, detailed evidence. Describes complex relationships between concepts using appropriate terminology and conventions. Provides responses that are comprehensive and contain detailed information. Consistently selects and manipulates equations to solve complex problems. Provides logically sequenced working and expresses answers using correct units and significant figures.
	Science inquiry skills Formulates a testable hypothesis that describes a quantifiable relationship between the dependent and independent variables. Plans and conducts investigations, identifying appropriate variables and explaining how they are controlled. Describes experimental method in detail and accurately collects valid and reliable data. Consistently organises and processes data accurately, including uncertainty of measurement. Presents data logically in a range of forms, including graphs, tables and diagrams. Comprehensively explains trends using quantitative data, where appropriate, as evidence to draw conclusions that relate to the hypothesis. Evaluates the experimental method and provides specific and relevant suggestions to improve the reliability of the data collected. Communicates detailed information and concepts logically and coherently. Consistently uses appropriate terminology and conventions.

B	**Understanding and applying concepts** Applies models and scientific principles to accurately explain and link simple, and some complex, phenomena. Supports responses with appropriate examples and accurate diagrams. Often applies scientific knowledge to accurately explain unfamiliar contexts or examples, sometimes lacking detail. Selects and evaluates scientific information from a variety of sources to present logical arguments, which are supported by relevant evidence. Describes relationships between concepts using appropriate terminology and conventions. Provides responses that are detailed and contain relevant information. Selects and manipulates equations to solve simple multiple-step problems. Provides adequate working and generally expresses answers using correct units and significant figures.
	Science inquiry skills Formulates a testable hypothesis that describes a relationship between the dependent and independent variables. Plans and conducts investigations, identifying and controlling appropriate variables. Describes the experimental method and accurately collects appropriate data. Often organises and processes data accurately.

	Presents data logically in a range of forms, including graphs, tables and diagrams. Explains trends using some quantitative data, where appropriate, and uses evidence to draw conclusions that relate to the hypothesis. Evaluates the experimental method and provides relevant suggestions to improve the reliability of the data collected. Communicates information and concepts logically. Often uses appropriate terminology and conventions.

C	**Understanding and applying concepts** Applies models and scientific principles to describe simple systems and processes. Provides examples in some responses. Draws simple diagrams that lack detail. Sometimes applies scientific knowledge to unfamiliar contexts and provides generic responses. Selects some scientific information to provide generalised arguments or statements, which are supported by some evidence. Describes simple relationships between concepts using appropriate terminology and conventions. Provides responses that lack detail and may include irrelevant information. Selects and manipulates equations and data to solve simple problems. Provides adequate working that may contain errors and expresses answers with some errors in units and significant figures.
	Science inquiry skills Formulates a testable hypothesis that includes the dependent and independent variables. Plans and conducts investigations identifying and controlling some variables. Briefly outlines the experimental method and collects data. Organises and processes data with minor errors or omissions. Presents data in basic graphs, tables and diagrams. Describes trends in data and draws simple conclusions that may not link to the hypothesis. Provides general suggestions to improve the reliability of the data collected. Communicates information and concepts simply. Sometimes uses appropriate terminology and conventions.

D	**Understanding and applying concepts** Incorrectly applies scientific models and principles to describe systems and processes. Presents diagrams which are incomplete or incorrect. Inconsistently applies scientific knowledge to unfamiliar contexts. Presents statements of ideas with limited development of an argument, without providing sufficient supporting evidence. Incorrectly describes the relationships between concepts using everyday language. Provides responses that contain errors, inconsistencies and misconceptions. Performs simple problems with errors and omissions. Provides working out that is confused and consistently expresses answers without appropriate units and significant figures.
	Science inquiry skills Identifies one or more relevant variables. Plans investigations without controlling variables. Describes an experimental method that lacks detail. Organises and processes data with significant errors or omissions. Presents data that is unclear, insufficient and lacks appropriate processing.

	Identifies trends in data incorrectly or overlooks trends and draws simple conclusions that are not always supported by the data or are not related to the hypothesis. Provides suggestions to improve the reliability of the data collected that may not be feasible. Communicates information ineffectively. Rarely uses appropriate terminology and conventions.
E	Does not meet the requirements of a D grade and/or has completed insufficient assessment tasks to be assigned a higher grade.

Appendix 2 – Glossary

This glossary is provided to enable a common understanding of key terms.

Absolute uncertainty	Estimate of the dispersion of the measurement result; the range of values around the measurement result that is most likely to include the true value.
Accuracy	The extent to which a measurement result represents the quantity it purports to measure; an accurate measurement result includes an estimate of the true value and an estimate of the uncertainty.
Algebraic representation	A set of symbols linked by mathematical operations; the set of symbols summarise relationships between variables.
Amplitude	The displacement of a point on an oscillating object from the centre of oscillation.
Analyse	Consider in detail for the purpose of finding meaning or relationships, and identifying patterns, similarities and differences.
Animal ethics	Animal ethics involves consideration of respectful, fair and just treatment of animals. The use of animals in science involves consideration of replacement (substitution of insentient materials for conscious living animals), reduction (using only the minimum number of animals to satisfy research statistical requirements) and refinement (decrease in the incidence or severity of 'inhumane' procedures applied to those animals that still have to be used).
Anomalous data	Data that does not fit a pattern; outlier.
Characteristic	Distinguishing aspect (including features and behaviours) of an object, material, living thing, or event.
Classify	Arrange into named categories in order to sort, group or identify.
Collaborate	Work with others to perform a specific task.
Conclusion	A judgement based on evidence.
Contemporary science	New and emerging science research and issues of current relevance and interest.
Cultural relativism	The practice of describing the beliefs, customs and practices of another culture from a neutral point of view, rather than from the perspective of the observing individual's own culture.
Data	The plural of datum; the measurement of an attribute, for example, the volume of gas or the type of rubber. This does not necessarily mean a single measurement – it may be the result of averaging several repeated measurements. Data may be quantitative or qualitative and be from primary or secondary sources.
Design	Plan and evaluate the construction of a product or process, including an investigation.
Discrete data	Quantitative data consisting of a number of separate values where intermediate values are not permissible.
Energy	The potential to move or bring about changes; the higher the energy content the greater the impact when it is transformed or transferred.
Environment	All the surroundings, both living and non-living.
Ethnocentrism	The practice of describing the beliefs, customs and practices of another culture from the perspective of the observing individual's own culture.
Evaluate	Examine and judge the merit or significance of something, including processes, events, descriptions, relationships or data.

Evidence	In science, evidence is data that is considered reliable and valid and which can be used to support a particular idea, conclusion or decision. Evidence gives weight or value to data by considering its credibility, acceptance, bias, status, appropriateness and reasonableness.
Experimental (investigation)	An investigation that involves carrying out a practical activity.
Field	A position in space where susceptible objects experience (are affected by) a force or acquire potential energy as they are 'worked' into that position; gravitational fields affect the mass of an object; electric fields affect charged objects; magnetic fields affect ferromagnetic objects; electromagnetic fields affect charge carriers in matter.
Field work	Observational research undertaken in the normal environment of the subject of the study.
Force	A push or pull between objects which may cause one or both objects to change speed and/or the direction of their motion (i.e. accelerate) or change their shape. Scientists identify four fundamental forces: the gravitational, the electromagnetic (involving both electrostatic and magnetic forces), the weak nuclear forces and the strong nuclear forces. All interactions between matter can be explained as the action of one, or a combination, of the four fundamental forces.
Fundamental forces	Four fundamental forces have been identified. They are, in order from strongest to weakest, the strong nuclear, the electromagnetic, the weak nuclear and the gravitational.
Genre	The categories into which texts are grouped; genre distinguishes texts on the basis of their subject matter, form and structure (for example, scientific reports, field guides, explanations, procedures, biographies, media articles, persuasive texts, narratives).
Hypothesis	A scientific statement based on the available information that can be tested by experimentation. When appropriate, the statement expresses an expected relationship between the independent and dependent variables for observed phenomena.
Intensity	The average rate of flow of energy per unit area.
Investigation	A scientific process of answering a question, exploring an idea or solving a problem that requires activities, such as planning a course of action, collecting data, interpreting data, reaching a conclusion and communicating these activities. Investigations can include observation, research, field work, laboratory experimentation and manipulation of simulations.
Law	A statement describing invariable relationships between phenomena in specified conditions, frequently expressed mathematically.
Linear motion	Straight line motion or an idealisation of approximately straight line motion when an object moves from one place to another.
Longitudinal	As in longitudinal waves, where the direction of oscillation of particles is parallel to the direction of energy transfer.
Material	A substance with particular qualities or that is used for specific purposes.
Matter	A physical substance; anything that has mass and occupies space.
Measurement discrepancy	The difference between the measurement result and a currently accepted or standard value of a quantity.
Media texts	Spoken, print, graphic or electronic communications with a public audience. Media texts can be found in newspapers, magazines and on television, film, radio, computer software and the internet.
Mode	The various processes of communication – listening, speaking, reading/viewing and writing/creating.
Model	A representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea.

Newtonian determinism	The philosophical consequence of Newton's Laws of Motion, viz., that it is possible in principle to deduce all consequences of interactions between objects; sometimes referred to as the 'clockwork Universe'.
Nuclide	The range of atomic nuclei associated with a particular atom which is defined by its atomic number and the various isotopes of that atom as identified by the mass number.
Oscillate	To and fro motion about an equilibrium position; characterised by the period of its motion or velocity and acceleration at different positions as it moves.
Primary data	Data collected directly by a person or group.
Primary source	Information created by the person or persons directly involved in a study, investigation or experiment or observing an event.
Property	Attribute of an object or material, normally used to describe attributes common to a group.
Qualitative data	Information that is not numerical in nature.
Quantitative data	Numerical information.
Random error	Uncontrollable effects of the measurement equipment, procedure and environment on a measurement result; the magnitude of random error for a measurement result can be estimated by finding the spread of values around the average of independent, repeated measurements of the quantity.
Reductionism	A philosophical approach that starts by removing all objects from a system, then returning them one-by-one and noting the relationships between them; a process of defining basic concepts and relationships from simplest to more complex.
Reliability	The degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute, achieving similar results for the same population.
Reliable data	Data that has been judged to have a high level of reliability; reliability is the degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute, achieving similar results for the same population.
Report	A written account of an investigation.
Representation	A verbal, visual, physical or mathematical demonstration of understanding of a science concept or concepts. A concept can be represented in a range of ways and using multiple modes.
Research	To locate, gather, record, attribute and analyse information in order to develop understanding.
Research ethics	Norms of conduct that determine ethical research behaviour; research ethics are governed by principles, such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics.
Resonance	The effect achieved when one system with a natural predisposition to accept energy impacting it and is characterised by a particular frequency or frequencies.
Risk assessment	Evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities. Requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate.
Scientific language	Terminology that has specific meaning in a scientific context.
Secondary data	Data collected by a person or group other than the person or group using the data.
Secondary source	Information that has been compiled from records of primary sources by a person or persons not directly involved in the primary event.
Significant figures	The use of place value to represent a measurement result accurately and precisely.
Simulation	A representation of a process, event or system which imitates a real or idealised situation.

Sustainable	Supports the needs of the present without compromising the ability of future generations to support their needs.
System	A group of interacting objects, materials or processes that form an integrated whole. Systems can be open or closed.
Systematic error	The contribution to the uncertainty in a measurement result that is identifiable and quantifiable, for example, imperfect calibration of measurement instruments.
Technology	The development of products, services, systems and environments, using various types of knowledge, to meet human needs and wants.
Theory	A set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena. Theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power.
Thermodynamics	The study of heating processes and their relationships with various forms of energy and work; is concerned with characteristics of energy, such as temperature, entropy and pressure and their inter-relationships.
Thought experiments	A process whereby the consequences of a principle, postulate or theory are examined without necessarily undertaking the experiment.
Transverse	As in transverse waves, where the direction of oscillation of particles is perpendicular to the direction of energy transfer.
Trend	General direction in which something is changing.
Uncertainty	Range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment.
Universal law	The applicability of the relationships expressed in the law extends from Earth to the known universe.
Validity	The extent to which tests measure what was intended; the extent to which data, inferences and actions produced from tests and other processes are accurate.
Work	A concept that relates force to energy; defined as the product of a force and the displacement of an object on which it acts.