DRAFT SENIOR SECONDARY CURRICULUM – PHYSICS

Organisation

1. Overview of senior secondary Australian Curriculum

ACARA has developed draft senior secondary Australian Curriculum for English, Mathematics, Science and History according to a set of design specifications (see http://www.acara.edu.au/curriculum/development_of_the_australian_curriculum.html). The ACARA Board approved these specifications following consultation with state and territory curriculum, assessment and certification authorities.

Senior secondary Australian Curriculum will specify content and achievement standards for each senior secondary subject. Content refers to the knowledge, understanding and skills to be taught and learned within a given subject. Achievement standards refer to descriptions of the quality of learning (the depth of understanding, extent of knowledge and sophistication of skill) demonstrated by students who have studied the content for the subject.

The senior secondary Australian Curriculum for each subject has been organised into four units. The last two units are cognitively more challenging than the first two units. Each unit is designed to be taught in about half a 'school year' of senior secondary studies (approximately 50–60 hours duration including assessment). However, the senior secondary units have also been designed so that they may be studied singly, in pairs (that is, year-long), or as four units over two years. State and territory curriculum, assessment and certification authorities are responsible for the structure and organisation of their senior secondary courses and will determine how they will integrate the Australian Curriculum content and achievement standards into courses. They will also provide any advice on entry and exit points, in line with their curriculum, assessment and certification requirements.

States and territories, through their respective curriculum, assessment and certification authorities, will continue to be responsible for implementation of the senior secondary curriculum, including assessment, certification and the attendant quality assurance mechanisms. Each of these authorities acts in accordance with its respective legislation and the policy framework of its state government and Board. They will determine the assessment and certification specifications for their courses that use the Australian Curriculum content and achievement standards and any additional information, guidelines and rules to satisfy local requirements.

These draft documents should not, therefore, be read as proposed courses of study. Rather, they are presented as draft content and achievement standards that will provide the basis for senior secondary curriculum in each state and territory in the future. Once approved, the content and achievement standards would subsequently be integrated by states and territories into their courses.

2. Senior Secondary Science Subjects

The Australian Curriculum Senior Science subjects build on student learning in the Foundation to Year 10 Science curriculum and include:

- Biology
- Chemistry
- Earth and Environmental Science
- Physics.

3. Structure of Physics

Units

In Physics, students develop their understanding of the core concepts, models and theories that describe, explain and predict physical phenomena. There are four units:

Unit 1: Models in Thermal, Nuclear and Electrical Physics

Unit 2: Models of Motion, Waves, Sound and Light

Unit 3: From Force to Field models of Gravity and Electromagnetism

Unit 4: Current Models of Space-time, Energy and Matter.

In Units 1 and 2, students further elaborate the atomic and wave models introduced in the F-10 Australian Curriculum: Science. In Unit 1, students investigate the use of the kinetic particle model to explain heating processes; the nuclear model of the atom to explain radioactivity and nuclear reactions; and the electric charge model to explain energy transfers and transformations in electric circuits. In Unit 2, students use the force model to describe, explain and predict linear motion and investigate the application of wave models to light and sound phenomena.

In Units 3 and 4, students are introduced to more complex models that enable description, explanation and prediction of a wider range of phenomena, including, in Unit 4, very high speed motion and very small scale objects. In Unit 3, students investigate both models of motion in gravitational, electric and magnetic fields to explain how forces act at a distance, and the use of the theory of electromagnetism to explain the production and propagation of electromagnetic waves. In Unit 4, students investigate how shortcomings in existing theories led to the development of the special theory of relativity, the quantum theory of light and matter and the Standard Model.

Each unit includes:

- Unit descriptions – A short description of the purpose and rationale for each unit
- Learning outcomes – Six to eight statements describing the expected learning as a result of studying the unit
- Content descriptions – Content descriptions describe the core content to be taught and learned and are organised in three strands:
    - *Science Inquiry Skills* content descriptions are written for the entire unit; based on the generic science inquiry skills
    - *Science Understanding* and *Science as a Human Endeavour* content descriptions are written for each sub-section within the unit.

Organisation of content

Science strand descriptions

The Australian Curriculum: Science has three interrelated strands: *Science Understanding, Science as a Human Endeavour* and *Science Inquiry Skills*. These strands are used to organise the Science learning area from Foundation to Year 12. In the practice of science, the three strands are closely integrated; the work of scientists reflects the nature and development of science, is built around scientific inquiry and seeks to respond to and influence society's needs. Students' experiences of school science should mirror and connect to this multifaceted view of science.

To achieve this, the three strands of the Australian Curriculum: Science should be taught in an integrated way. The content descriptions of the three strands have been written so that this integration is possible in each unit.

In the Senior Secondary Science subjects, the three strands of *Science Understanding, Science as a Human Endeavour* and *Science Inquiry Skills* build on students' learning in the F-10 Australian Curriculum: Science.

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 and models to new situations. Conceptual models in science can include diagrams, physical replicas, mathematical representations, word-based analogies (including laws and principles) and computer simulations. Models involve selection of the aspects of the system/s to be included in the model, and thus have underpinning approximations, assumptions and limitations.

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

Science as a Human Endeavour

Through science, humans seek to improve their understanding and explanations of, and ability to predict phenomena in, the natural world. Since science involves the construction of explanations based on evidence, science concepts, models and theories can be changed as new evidence becomes available, often through the application of new technologies. Science influences society by posing, and responding to, social and ethical questions, and scientific research is itself influenced by the needs and priorities of society.

This strand highlights the development of science as a unique way of knowing and doing, the communication of science and the role of science in decision making and problem solving. In particular, this strand develops both students' understanding of science as a community of practice and their appreciation that science knowledge is generated from consensus within a group of scientists and is therefore dynamic and involves critique and uncertainty. It acknowledges that in making decisions about science practices and applications, ethical and social implications must be taken into account.

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. The investigation design will depend on the context and subject of the investigation.

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

Through the Senior Secondary Science subjects, students will continue to develop generic science inquiry skills, building on the skills acquired in the F-10 Australian Curriculum: Science. These generic skills are described below and will be explicitly taught and assessed in each unit. In addition, each unit provides specific skills to be taught within the broader generic science inquiry skills; these specific skills align with the *Science Understanding* and *Science as a Human Endeavour* content of the unit. The generic science inquiry skills are:

- Identify, research and construct questions for investigation, proposing hypotheses and predicting possible outcomes

- Design investigations, including: making decisions about the procedure to be followed, the materials required and the type and amount of primary and/or secondary data to be collected; conducting risk assessments; and considering ethical research
- Conduct investigations, including using equipment and techniques safely, competently and methodically, for valid and reliable collection of data
- Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships, and recognise uncertainty and limitations in data; and select, synthesise and use evidence to construct and justify conclusions
- 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 to communicate conceptual understanding, solve problems and make predictions
- Communicate information or findings to specific audiences and for specific purposes using appropriate language, nomenclature, text types and modes

The Senior Secondary Science subjects have been designed to accommodate, if appropriate, an extended scientific investigation with each pair of units. States and territories will determine whether there are any requirements related to an extended scientific investigation as part of their course materials.

Organisation of achievement standards

The Physics achievement standards are organised by two dimensions; ‘Physics Concepts, Models and Applications’, and ‘Physics Inquiry Skills’. They describe five levels of student achievement.

‘Physics Concepts, Models and Applications’ describes the knowledge and understanding students demonstrate with reference to the content of the *Science Understanding* and *Science as a Human Endeavour* strands of the curriculum. ‘Physics Inquiry Skills’ describes the skills students demonstrate when investigating the content developed through the *Science Understanding* and *Science as a Human Endeavour* strands.

4. Links to F-10

Progression from the F-10 Australian Curriculum: Science

The Senior Secondary Physics curriculum contnues to develop student understanding and skills from across the three strands of the F-10 Australian Curriculum: Science. In the *Science Understanding* strand, the Physics curriculum draws on knowledge and understanding from across the four sub-strands of Biological, Physical, Chemical and Earth and Space sciences.

In particular, the Physics curriculum continues to develop the key concepts introduced in the Physical Sciences sub-strand, that is, that forces affect the behaviour of objects; and that energy can be transferred and transformed from one form to another.

Mathematical skills expected of students studying Physics

The Physics curriculum requires students to use the mathematical skills they have developed through the F-10 Australian Curriculum: Mathematics, in addition to the numeracy skills they have developed through the *Science Inquiry Skills* strand of the Australian Curriculum: Science.

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 conclusions, claims or arguments. 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, and, as appropriate, to specify confidence intervals to indicate accuracy.

Students are required to represent numerical data so that trends, patterns and relationships can be identified. This includes representing data in tables and selecting appropriate graphical forms to identify or demonstrate relationships. Students will analyse graphical representations of data to identify relationships between variables, including identification of linear and non-linear relationships, and comparison of these with the form of graphs produced by standard algebraic relationships, including circles, parabolas, and exponentials. Students are required to use digital technologies and graphing software to explore these relationships. Teachers need to teach inverse and inverse square relationships to students as they are important in physics, but are not part of the Year 10 Australian Curriculum: Mathematics.

In addition to manipulation, representation and analysis of data, students will be required to create, use and interpret graphical and algebraic representations of physical systems and manipulate them (including rearranging equations, substituting values, identifying unknowns and manipulating quantities expressed in scientific notation) to solve problems and make predictions. Students are required to solve equations with one unknown, monic quadratic equations, and simultaneous equations involving two unknowns. Students are required to apply statistical analysis techniques to firsthand and second-hand data presented in the form of dot plots, histograms, box plots and scattergrams to make comparisons and form conclusions.

5. Representation of General Capabilities

General capabilities that are specifically covered in Physics include *Literacy*, *Numeracy*, *Information and Communication Technology (ICT) capability*, *Critical and creative thinking* and *Ethical behaviour*.

Literacy is of fundamental importance in students' development of *Science Inquiry Skills*. Students are taught to read, understand and gather information presented in a wide range of genres, modes and representations (including text, flow diagrams, symbols, graphs and tables). They are taught how to communicate processes and ideas logically and fluently and to structure evidence-based arguments.

Numeracy is key to students' ability to make and record observations, order, represent and analyse data and interpret trends and relationships. Physics requires students to engage in statistical analysis of data, including issues relating to reliability and probability, and to manipulate linear mathematical relationships to calculate and predict values.

Critical and creative thinking is inherent in the science inquiry process, which requires the ability to construct questions and hypotheses; develop investigation methods; interpret and evaluate data; interrogate, select and cross reference evidence; and analyse interpretations, conclusions and claims.

Ethical behaviour involves students exploring the ethics of their own and other others' actions. Students are required to 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 explore 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 claims and to inform ethical decisions about a range of social, environmental and personal issues and applications of science.

Information and Communication Technology (ICT) capability is a key part of *Science Inquiry Skills.* Students develop ICT capability when they research science concepts and applications, investigate scientific phenomena, and communicate their scientific understandings. In particular, they employ their ICT capability to access information; collect, analyse and represent data; model and interpret concepts and relationships; and communicate science ideas, processes and information.

There are also opportunities within Physics to develop the general capabilities of *Intercultural understanding* and *Personal and social capability*, with an appropriate choice of activities by the teacher.

6. Representation of Cross-curriculum Priorities

In Physics, the Cross-curriculum Priority of *Sustainability* provides authentic contexts for exploring, investigating and understanding the function and interactions of physical systems. Physics explores a wide range of physical systems that operate at different time 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. Relationships including cycles and cause and effect are explored, and students develop observation and analysis skills to examine these relationships in the world around them.

In Physics, 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 science to predict possible effects of human and other activity and to develop management plans or alternative technologies that minimise these effects.

In addition, there are opportunities for teachers, with an appropriate choice of activities, to include *Aboriginal and Torres Strait Islander histories and cultures* and *Asia and Australia's engagement with Asia*.

7. 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 *Workplace Health and Safety Act 2011*, in addition to relevant state or territory health and safety guidelines.

When state and territory curriculum authorities integrate the Australian Curriculum into local courses they will include more specific advice on safety.

For further information about relevant guidelines, contact your state or territory curriculum authority.

8. Animal ethics

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*, 7th edition (2004) (http://www.nhmrc.gov.au/guidelines/publications/ea16), in addition to relevant state or territory guidelines.

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DRAFT SENIOR SECONDARY CURRICULUM – PHYSICS

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 and laws 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.

Physics uses qualitative and quantitative models to visualise, explain and predict physical phenomena. These models are based on, and their predictions are tested by, making observations and quantitative measurements. In this subject, students gather, analyse and interpret primary and secondary data to investigate some of the most important models used by physicists, including the nuclear model of the atom, the kinetic particle model, wave and ray models, and field models.

Students investigate how the development of a unified concept of energy enabled a coherent explanation of diverse phenomena and provides a powerful tool for analysing how systems interact throughout the universe on multiple scales. Students learn how more sophisticated models, including the quantum model of the atom and relativity, are needed to explain more complex phenomena and how new observations can lead to models 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. Students consider how physics contributes to such diverse areas 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 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 subject will also provide a foundation in physics knowledge, understanding and skills for those students who wish to pursue tertiary study in science, engineering and technology.

Aims

Physics 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 by models that provide a reliable basis for action
- understanding of the way in which existing models are refined and new models are developed in physics
- understanding that decisions about personal, local and global issues involving physics and its applications should be evidence-based and responsive to ethical considerations
- investigative skills, including the design and conduct of investigations, collection and analysis of qualitative and quantitative data, interpretation of data and evidence, and the use of models to explore, explain and predict events
- commitment to accurate and precise measurement, reliance on evidence, and to scepticism and intellectual rigour as foundations of scientific practice and decision-making
- ability to construct scientific descriptions and explanations using appropriate genres including reports, essays and multimedia presentations.

Unit 1: Models in Thermal, Nuclear and Electrical Physics

Unit description

In this unit students explore the way physics is used to describe, explain and predict the energy transfers and transformations that are pivotal to modern industrial societies. An understanding of heating processes, nuclear reactions and electricity is essential to appreciate how global energy needs are met.

Students apply the kinetic particle model and thermodynamics concepts to assess energy sources used today, and to investigate potential energy sources for the future. They explore how knowledge of heating processes informs the design of industrial systems that produce, transfer and transform energy in domestic and other settings. They apply the nuclear model of the atom to investigate radioactivity, and how nuclear reactions convert mass into energy. They evaluate the benefits and risks of using nuclear processes for a range of applications.

Students use the electric charge model to analyse, explain and predict electrical phenomena and the transfer and transformation of energy in electrical circuits. They consider how electrical technologies have transformed, and continue to transform, society, and evaluate how improved energy efficiency can be achieved both through technologies and social regulation.

Students develop understandings of a range of mathematical and symbolic representations to describe, explain and predict energy transfers and transformations in heating processes, nuclear reactions and electrical circuits. They develop their inquiry skills through primary and secondary investigations, including analysing radioactive decay and a range of simple electrical circuits.

Learning outcomes

By the end of this unit, students:

- understand how the kinetic particle model and thermodynamics concepts describe and explain heating processes
- understand how the nuclear model of the atom explains radioactivity, fission, fusion and the properties of radioactive nuclides
- understand how the electric charge model explains electrical phenomena and the transfer and transformation of energy in electrical circuits
- understand how models that explain heating processes, nuclear physics and energy changes in electrical circuits have developed, and how they have been applied to meet the energy needs of society and to develop other technologies
- use algebraic and graphical models to calculate, analyse and predict the quantities of energy involved in heating processes, nuclear reactions and electrical circuits
- use science inquiry skills to design, conduct and analyse safe and effective investigations into heating processes, nuclear physics and electrical circuits, and to communicate methods and findings using appropriate conventions
- evaluate claims about heating processes, nuclear reactions and electrical technologies and justify assessments with reference to empirical evidence and ethical considerations.

Content descriptions

Science Inquiry Skills (Physics Unit 1)

- Identify, research, construct and refine 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 using thermometers, data loggers, calorimeters, energy sources, Geiger counters and circuit components, safely, competently and methodically for accurate and reliable collection of data
- Represent data in meaningful and useful ways, including the use of appropriate SI units and symbols to indicate the accuracy of individual and multiple measurements; organise and analyse data to identify trends, patterns and relationships; identify uncertainty and limitations in data; select, synthesise and use evidence to make and justify conclusions
- Evaluate models, processes, claims and conclusions by considering the quality of available evidence; use reasoning to construct scientific arguments
- Select, construct and use appropriate representations, including text and graphic representations of empirical and theoretical relationships, flow diagrams, nuclear equations 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
  To view the mathematical representations related to this unit, CLICK HERE
- Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, text types and modes, including scientific reports

Kinetic particle model – heating processes

Science Understanding

- Thermal energy can be transferred between and within systems by conduction, convection and/or radiation
- The kinetic particle model describes matter as consisting of particles in constant motion, except at absolute zero; this model explains energy transfer in heating processes in terms of particle interactions
- All systems have internal thermal energy due to the vibration and/or movement of particles in the system
- Temperature is a measure of the average kinetic energy of particles in a system
- Provided a substance does not change state, the amount of temperature change is proportional to the amount of energy added to or removed from the substance; the constant of proportionality is called the 'specific heat capacity' of the substance
- Change of state involves internal energy changes to form or break bonds between atoms or molecules; latent heat is the energy required to be added to or removed from a system to change the state of the system
- Two systems in contact transfer energy between particles so that eventually the systems reach the same temperature, that is, they are in thermal equilibrium
- A system with thermal energy has the capacity to do mechanical work (that is, to apply a force over a distance); when work is done the internal energy of the system changes
- Because energy is conserved, the change in internal energy of a system is equal to the energy added or removed by heating plus the work done on or by the system
- Energy transfers and transformations in mechanical systems (for example, internal and external combustion engines, electric motors) always result in the production of thermal energy, so that the usable energy is reduced and the system cannot be 100 per cent efficient

Science as a Human Endeavour

- Competing models and theories can coexist until more evidence is available to support one to supersede the other (for example, the caloric theory and the kinetic particle model originally existed as alternative theories, but in the mid-nineteenth century the kinetic particle was accepted as providing a better explanation for a wider range of energy related phenomena)
- The development of heating technologies that use conduction, convection and/or radiation have had, and continue to have, significant social, economic and environmental impacts (for example, steam technologies were pivotal to the Industrial Revolution and continue to be used extensively in electrical power generation and industrial applications today)
- Scientific evidence, ethical considerations and community concerns contribute to the development of standards, regulations and laws concerning safe management of heat in

domestic, industrial and commercial settings (for example, temperature ranges for worker safety, requirements for insulation, shielding or heat reduction, personal protective measures for workers)

- Thermodynamics concepts enable evaluation of economically, socially and environmentally viable alternatives to fossil fuels as energy sources for heating processes (for example, solar heating, geothermal energy)

The nuclear model of the atom — ionising radiation and nuclear reactions

Science Understanding

- The nuclear model of the atom describes the atom as consisting of an extremely small and dense nucleus made up of positively charged protons and uncharged neutrons surrounded by negatively charged electrons
- Nuclear stability is the result of the strong nuclear force between nucleons, which operates over a very short distance and is stronger than the electrostatic repulsion between protons in the nucleus
- Some nuclides are unstable and spontaneously decay, emitting alpha, beta and/or gamma radiation over time until they become stable nuclides
- The rate of emission of radiation is inversely proportional to the half-life of the nuclide
- Alpha, beta and gamma radiation have sufficient energy to cause ionisation of atoms and somatic and genetic effects in living things; different radiations have different effects on living things
- Nuclear reactions involve much greater mass changes per atom than chemical reactions and release significantly more energy than chemical reactions
- Einstein's mass/energy relationship, which applies to chemical and nuclear reactions, enables the energy released in nuclear reactions to be determined from the mass change in the reaction
- Alpha and beta decay are examples of spontaneous transmutation reactions while artificial transmutation is a managed process that changes one nuclide into another
- Neutron induced nuclear fission is a reaction in which a heavy nuclide captures a neutron and then splits into two smaller radioactive nuclides, with the release of neutrons and energy
- A fission chain reaction is a self-sustaining process that may be controlled to produce thermal energy, or uncontrolled to release energy explosively
- Nuclear fusion is a reaction in which light nuclides combine to form a heavier nuclide, with the release of energy
- More energy is released per nucleon in nuclear fusion than nuclear fission because a greater percentage of the mass is transformed into energy

Science as a Human Endeavour

- The discovery of new phenomena can prompt revision of models and theories (for example, the discovery of radioactivity in the late nineteenth century contributed to significant revisions of the model of the atom and provided the impetus for research into the nature of the forces that hold the atom together)
- Understanding of the role of nuclear fusion in the energy emissions from stars significantly developed scientists' understanding of the lifecycles of stars and the spatial dimensions of the universe; predictions of the Sun's lifecycle have consequences for future life on Earth
- Qualitative and quantitative analysis of relative risk are used to inform community debates about the use of radioactivity and nuclear reactions for a range of applications and purposes (for example, radiopharmaceuticals, nuclear power generation)

Electric charge model - electrical circuits

Science Understanding

- Electrical circuits enable electrical energy to be transferred efficiently over large distances and transformed into a range of other useful forms of energy including thermal, light and kinetic energy
- The functionality of an electric circuit is determined by the components in it and the way they are interconnected
- The electric charge model assumes that current is carried by discrete charge carriers and that the charge is conserved at all points in an electric circuit
- Energy is conserved in the energy transfers and transformations that occur in an electrical circuit
- The energy available to charges moving in an electric circuit is measured using electric potential difference, which is defined as the change in potential energy per unit charge between two defined points in the circuit
- Various forms of energy can be used to separate positive and negative charge carriers; charge separation produces an electrical potential difference that can be used to drive current in circuits
- The power transformed by a circuit component is the product of the electric potential difference across the component and the current in the component
- Resistance for ohmic and non-ohmic components is defined as the ratio of potential difference across the component to the current in the component
- Circuit analysis and design uses the electric charge model to calculate the potential difference across, the current in, and the power supplied to components in series, parallel and series/parallel circuits

Science as a Human Endeavour

- Development of models and theories can take several decades and requires the cumulative work of multiple scientists who build on the findings of their predecessors and share their own theories and data (for example, understanding of electric charge as a discrete entity involved a range of scientists' findings, such as Faraday's electrolysis experiments, the discovery of the electron by JJ Thomson and Millikan's oil-drop experiment)
- The development of electrical technologies for industrial and residential use in the late nineteenth century transformed society; electrical power is now a core element of modern societies
- Increasing use of electrical energy has environmental impacts and this has informed government programs, private investment, community action and incentives directed towards the development of energy efficient systems and devices (for example, home-based photovoltaic mains power, light emitting diodes and fluorescent lamps)

Mathematical representations and relationships (Physics Unit 1)

All measurement units are Système Internationale (SI), unless otherwise specified.

Important constants used in algebraic representations are expressed in scientific notation.

Kinetic particle model – heating processes

- $Q = mC\Delta T$

  $Q =$ *energy gain / energy loss,* $m =$ *mass of object,* $C =$ *specific heat capacity of the object,* $\Delta T =$ *temperature change*

- $Q = mL$

  $Q =$ *energy gain / energy loss,* $L =$ *latent heat capacity of the material,* $m =$ *mass of object*

- $\eta = \frac{energy\ output}{energy\ input} \times \frac{100}{1}\%$

  $\eta =$ *efficiency*

Nuclear model of the atom – ionizing radiation and nuclear reactions

- $\Delta N = \left(\frac{1}{2}\right)^n N_o$ *(for whole numbers of half-lives only)*

  $\Delta N =$ *change in number of nuclides,* $n =$ *number of half-lives,* $N_o =$ *original number of nuclides*

- $\Delta E = \Delta mc^2$

  $\Delta E =$ *energy change,* $\Delta m =$ *mass change,* $c =$ *speed of light (* 3×10^8 m s^{-1}*)*

- $\{dose\ equivalent\} = \{quality\ factor\} \times \{absorbed\ dose\}$

  $absorbed\ dose =$ *energy per kilogram of mass incident on an organism (unit: gray, Gy),* $quality\ factor =$ *empirical multiplier for each different form of radiation (dimensionless),* $dose\ equivalent =$ *effect of the particular form of radiation on the organism (unit: Sievert, Sv)*

Electric charge model - electrical circuits

- $I = \frac{q}{\Delta t}$

  I = current, q = change in charge, Δt = time interval

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

  V = potential difference, W = work, q = charge

- $R = \frac{V}{I}$

  For ohmic resistors, resistance (R) is a constant, V = potential difference, I = current

- $P = \frac{W}{\Delta t} = VI$

  P = power, W = work = energy transformed, Δt = time interval, V = potential difference, I = current

- Equivalent resistance for series components, I = constant

- $V_t = V_1 + V_2 + .. V_n$

- $R_t = R_1 + R_2 + .. R_n$

  I = current, V_t = total potential difference, V_n = the potential difference across each component, R_t = equivalent resistance, R_n = the resistance of each component

- Equivalent resistance for parallel components, V = constant

- $I_t = I_1 + I_2 + .. I_n$

- $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + .. \frac{1}{R_n}$

  V = potential difference, I_t = total current, I_n = current in each of the components, $\frac{1}{R_t}$ = the reciprocal of the equivalent resistance, $\frac{1}{R_n}$ = the reciprocal of the resistance of each component

Unit 2: Models of Motion, Waves, Sound and Light

Unit description

In this unit students develop an appreciation of how models of motion and wave models of light and sound can be used to describe, explain and predict a wide array of phenomena. Students build on simple models introduced in the F-10 Science curriculum and begin to explore the limitations of these models.

Students describe linear motion in terms of position and time data. They use concepts, models and physical laws to explain and predict motion and to examine the relationships between force, momentum and energy. Students investigate the development of ideas of motion, including Galileo's revolutionary use of reductionism, thought experiments and data. They investigate Newton's Laws and how they are used to improve the safety and efficiency of contemporary machines.

Students investigate large-scale wave phenomena, including waves on springs, and water, sound and earthquake waves, and compare the behaviour of these waves with the behaviour of light. This leads to an explanation of light phenomena including polarisation, interference and diffraction in terms of a wave model. Students investigate the importance of the wave model in a range of applications, including designing, measuring and regulating sound phenomena and the development of lens and fibre optic technologies.

Students develop their understanding of models of motion and wave models of sound and light through laboratory investigations. Through these investigations they develop skills in relating graphical representations of data to quantitative relationships between variables and they continue to develop skills in planning, conducting and interpreting the results of primary and secondary investigations.

Learning outcomes

By the end of this unit, students:

- understand that changes in motion can be represented graphically and algebraically, and that Newton's Laws of Motion explain these changes
- understand that waves transfer energy and that a wave model can be used to explain the behaviour of light and sound
- understand how models of motion and wave models have developed, and how they have been applied to describe, explain and predict phenomena and inform technological development
- use algebraic and graphical models to calculate, analyse and predict measureable quantities associated with linear and wave motion
- use science inquiry skills to design, conduct and analyse safe and effective investigations into straight-line motion, waves and light phenomena, and to communicate methods and findings using appropriate conventions
- evaluate claims about motion, sound and light-related phenomena and associated technologies and justify assessments with reference to evidence and ethical considerations.

Content descriptions

Science Inquiry Skills (Physics Unit 2)

- 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; consider research ethics
- Conduct investigations, including using data loggers, timers, distance and displacement measuring devices, wave modelling devices, optics kits, polaroid materials and diffraction gratings, safely, competently and methodically for accurate and reliable collection of data
- Represent data in meaningful and useful ways, *including the use of appropriate SI units and symbols to indicate the accuracy of individual and multiple measurements*; organise and analyse data to identify trends, patterns and relationships; identify uncertainty and limitations in data; select, synthesise and use evidence to make and justify conclusions
- Evaluate models, processes, claims and conclusions by considering the quality of available evidence; 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, wave diagrams and ray 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
  To view the mathematical representations related to this unit, CLICK HERE
- Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, text types and modes, including scientific reports

Models of force and linear motion

Science Understanding

- Position and time are used to describe the motion of objects, which can be modelled as point masses
- Because the universe has no absolute rest frame, motion must be measured with respect to a specified frame of reference
- Motion is described in terms of relationships between measurable scalar and vector quantities, including displacement, speed, velocity and acceleration for uniformly accelerated linear motion
- Graphic representations, including graphs and vectors, and/or equations of motion, can be used to explain and predict linear motion
- Vertical velocity is analysed by assuming the acceleration due to gravity is constant near Earth's surface
- Newton's Three Laws of Motion describe changes in the motion of objects in inertial frames as being caused by a resultant force acting on the object; a single resultant force may be found by geometric addition of vectors representing all the forces acting on an object
- Momentum is a property of moving objects; it is conserved in a closed system and may be transferred from one body to another when a force acts over a time interval
- Energy is conserved in isolated systems and is transferred from one object to another when a force is applied over a distance; this causes work to be done and changes to kinetic and/or gravitational potential energy of objects

Science as a Human Endeavour

- Accepted approaches to scientific inquiry change over time as new approaches are shown to provide valid, reliable data and contribute to model and theory development (for example, Galileo's use of reductionism, thought experiments and experimental data to develop an explanation of motion and its causes challenged the dominant Aristotelian explanation)
- Newton's laws of motion inform the design of, and safety legislation for, vehicle construction, and enable prediction and analysis of the relative safety and efficacy of vehicle structures under a range of circumstances (for example, collisions)

Mechanical models of waves

Science Understanding

- Mechanical waves are transverse or longitudinal periodic oscillations of particles in a medium that transfer energy through the medium; macroscopic variables such as pressure are used to measure wave oscillations in bulk materials
- The wave model relates the measurable quantities of position and time to amplitude, wavelength and frequency of particle oscillation and can be used to explain and predict the behaviour of water waves, waves in springs and some earthquake phenomena
- The wave model relates the measurable quantities of pressure and time to pressure amplitude, wavelength and frequency and can be used to explain and predict the behaviour of sound and some earthquake phenomena
- The velocity of wave propagation in a medium is dependent on the physical properties of the medium including elasticity and density
- The wave model can be used to explain phenomena related to reflection and refraction (for example, echoes, seismic phenomena)
- The superposition of waves in a medium may lead to the formation of standing waves and interference phenomena
- A mechanical system resonates when it is driven at one of its natural frequencies of oscillation; energy is transferred very efficiently into systems under these conditions

Science as a Human Endeavour

- The mechanical wave model has informed measurement of a wide variety of phenomena (for example, earthquakes, the inner structure of media, acoustic quality, sound pollution) and enabled the development of standard scales to describe and compare these phenomena
- Applications of mechanical wave understandings (for example, medical applications such as bionic devices, ultrasounds) have developed through collaboration between multi-disciplinary teams

Wave model of light

Science Understandings

- Light exhibits many wave properties; however, it cannot be modelled as a mechanical wave as it can travel through a vacuum
- A transverse wave model explains a wide range of light-related phenomena including reflection, refraction, total internal reflection, scattering, chromatic dispersion, diffraction, interference, polarisation and resonance
- The ray model of light is an alternative to the wave model; the laws of reflection and refraction can be shown using the ray model of light
- The speed of light is finite and many orders of magnitude greater than the speed of mechanical waves (for example, sound and water waves); its intensity decreases in an inverse square relationship with distance from its source
- Atoms of an element emit and absorb specific wavelengths of light that are unique to that element and can be used to identify the element; this is the basis of spectral analysis

Science as a Human Endeavour

- Models that were initially rejected can be revisited as more evidence becomes available (for example, the wave explanation of Young's double-slit demonstration was initially rejected until other physicists, including Fresnel and Poisson, showed that the wave model explained light phenomena)
- The wave theory of light, in concert with developing technologies, enables the manufacture of improved imaging devices, (for example, telescopes, microscopes, fibrescopes, camera lenses); these technologies have been critical to improved data collection in a range of endeavours (for example, cellular biology, medicine, astronomy, remote sensing)

Mathematical representations and relationships (Physics Unit 2)

All measurement units are Système International (SI), unless otherwise specified.

Important constants used in algebraic representations are expressed in scientific notation.

Models of force and linear motion

- $v = u + at,,\ \ s = ut + \frac{1}{2}at^2,\ \ v^2 = u^2 + 2as$

  $s =$ *distance interval,* $t =$ *time interval,* $u =$ *initial velocity,* $v =$ *final velocity,* $a =$ *acceleration*

- $a = \frac{F}{m}$

  $a =$ *acceleration,* $F =$ *force,* $m =$ *mass*

- *Where components of force and distance are parallel,* $W = Fs,\ \ W = \Delta E$

  $W =$ *work,* $F =$ *force,* $s =$ *displacement,* $\Delta E =$ *change in energy*

- $\Delta p = F\Delta t,\ \ \Delta p = m\Delta v$

  $\Delta p =$ *change in momentum,* $F =$ *force,* $m =$ *mass,* $\Delta v =$ *change in velocity,* $\Delta t =$ *time interval*

- $E_k = \frac{1}{2}mv^2$

  $E_k =$ *kinetic energy,* $m =$ *mass,* $v =$ *velocity*

- $\Delta E_p = mg\Delta h$

  $\Delta E_p =$ *change in potential energy,* $m =$ *mass,* $g =$ *acceleration due to gravity,* $\Delta h =$ *vertical distance interval*

- $\Sigma mv_{before} = \Sigma mv_{after}$

  $\Sigma mv_{before} =$ *vector sum of the momentum before the collision,* $\Sigma mv_{after} =$ *vector sum of the momentum after the collision*

- *For elastic collisions:* $\Sigma mv^2_{before} = \Sigma mv^2_{after}$

  $\Sigma mv^2_{before} =$ *sum of the kinetic energy before the collision,* $\Sigma mv^2_{after} =$ *sum of the kinetic energy after the collision*

Models of mechanical waves

- $v = f\lambda$

  $v = velocity,\ f = frequency,\ \lambda = wavelength$

- *angle of incidence = angle of reflection*

  $l = n\frac{\lambda}{2}$ *for strings attached at both ends and for pipes open at both ends*

- $l = (2n-1)\frac{\lambda}{4}$ *for pipes closed at one end*

  n = *whole numbers 1, 2, 3…relating to the harmonic,* l = *length of string or pipe,* λ = *wavelength of sound wave*

Wave model of light

- $v = f\lambda$

  $v = velocity,\ f = frequency,\ \lambda = wavelength$

- $I \propto \frac{1}{r^2}$

  I = *intensity,* r = *distance from the source*

- $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

  i = *incident angle (relative to the normal),* r = *angle of refraction (relative to the normal),* v_1 = *velocity in medium 1,* v_2 = *velocity in medium 2,* λ_1 = *wavelength in medium 1,* λ_2 = *wavelength in medium 2*

- *Constructive interference, path difference =* $n\lambda,\ n = 0, 1, 2, 3 \ldots$

- *Destructive interference, path difference =* $\left(n + \frac{1}{2}\right)\lambda,\ n = 0, 1, 2, 3 \ldots$

Achievement Standard Unit 1 and 2

	Physics Concepts, Models and Applications	Physics Inquiry Skills
A	For the physical systems studied, the student: • analyses the relationships between components and properties of physical systems qualitatively and quantitatively • analyses energy transfers and transformations in physical phenomena and associated technologies qualitatively and quantitatively • evaluates the theories and models used to describe physical systems and processes; the supporting evidence, and the aspects of the system they include • applies theories and models to make plausible predictions, explain new phenomena and solve complex problems For the physical science contexts studied, the student: • evaluates the origins and significance of key findings and the role of technologies, debate and review in the development of concepts, theories and models • evaluates how physics has been used in concert with other sciences to meet diverse needs and inform decision making; and the social, economic and ethical implications of these applications	The student competently and independently • utilises secondary sources to design and conduct safe, ethical investigations to collect valid, reliable data in response to a specific question, hypothesis or problem • analyses data sets to identify and evaluate causal and correlational relationships between variables • represents data accurately, justifies their selection of data as evidence and develops evidence-based conclusions • evaluates processes and claims; provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to communicate understanding, solve complex problems and make plausible predictions • communicates clearly and accurately in a wide range of modes, styles and genres (including scientific reports) for specific audiences and purposes
B	For the physical systems studied, the student: • explains the relationships between components and properties of physical systems qualitatively and quantitatively • explains energy transfers and transformations in physical phenomena and associated technologies qualitatively and quantitatively • describes key aspects of the theories and models used to describe the system • applies models of systems and processes to make plausible predictions, explain phenomena and solve problems For the physical science contexts studied, the student: • explains the origins and significance of key findings and the role of technologies, debate and review in the development of concepts, theories and models • explains how physics has been used to meet diverse needs and inform decision making; and the social, economic and ethical implications of these applications	The student competently and independently • designs and conducts safe, ethical investigations to collect valid, reliable data in response to a specific question, hypothesis or problem • analyses data sets to identify causal and correlational relationships between variables • represents data accurately , selects data as evidence and provides evidence for conclusions • evaluates processes and claims; provides a critique with reference to evidence and identifies possible improvements or alternatives • selects, constructs and uses appropriate representations to communicate ideas, solve problems and make predictions • communicates clearly and accurately in a range of modes, styles and genres (including scientific reports) for specific audiences and purposes

C	For the physical systems studied, the student: • describes the relationships between components and properties of physical systems qualitatively • describes energy transfers and transformations in physical phenomena and associated technologies qualitatively • describes the laws used to describe physical processes or relationships • applies understanding of physical processes to explain phenomena For the physical science contexts studied, the student: • describes key findings and the role of technologies and review in the development of concepts and theories • describes how physics has been used to meet needs and inform decision making; and some implications of these applications	The student competently and independently • designs and conducts safe, ethical investigations which enable collection of valid data in response to a specific question, hypothesis or problem • analyses data to identify relationships between variables • selects and represents data to demonstrate relationships and constructs conclusions based on data • assesses processes and claims and suggests improvements or alternatives • selects and uses appropriate representations to communicate ideas, solve problems and make predictions • communicates accurately in a range of modes, styles and genres (including scientific reports) for specific purposes
D	For the physical systems studied, the student: • describes how components of physical systems are related • describes the observable properties of physical systems and how they are affected by change • describes aspects of laws used to explain relationships in physical systems For the physical science contexts studied, the student: • identifies that physics ideas have changed over time and that science ideas are communicated within the science community • describes ways in which physics has been used in society to meet needs	The student competently and independently • designs and conducts safe, ethical investigations which enable collection of data in response to a specific question, hypothesis or problem • analyses data to identify cause and effect relationships • selects and represents data and presents simple conclusions based on data • considers processes and claims from a personal perspective • communicates using key representations in a range of modes and genres (including scientific reports)
E	For the physical systems studied, the student: • describes observable physical phenomena • describes how observable properties of physical phenomena are measured • uses understanding of cause and effect to describe observable changes to physical systems For the physical science contexts studied, the student: • identifies that physics ideas have changed over time • describes ways in which physics has been used in society	The student competently and independently • conducts safe, ethical investigations which enable collection of data • identifies trends in data and presents conclusions • considers claims from a personal perspective • communicates in a range of modes and genres

Unit 3: From Force to Field Models of 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 the previous units Newton's Laws of Motion were used to predict and explain the results of forces acting on bodies, but no mechanism was given to explain how forces such as gravity and magnetism are able to act at a distance. In this unit students are introduced to the field models of gravity and electromagnetism, which are used to explain and predict how forces act at a distance from the source of the force.

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, projectile and satellite motion. They investigate electromagnetic interactions and apply this knowledge in order to understand the operation of direct current (DC) and alternating current (AC) motors and generators, transformers, and AC electricity distribution systems. Students investigate the production of electromagnetic waves and examine the impact of some of the technologies that utilise electromagnetic waves.

Students develop their understanding of field models 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, including linear, uniform circular motion and projectile motion, can be described, explained and predicted 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 and those associated with motion in electric, magnetic and gravitational fields
- understand that models to explain electromagnetism have developed over time and have led to technologies including electric motors, generators, transformers and large-scale electricity supply systems

- use algebraic and graphical models to calculate, analyse and predict measureable quantities related to uniform circular motion, projectile motion, satellite motion, gravitational effects and electromagnetic phenomena
- use science inquiry skills to design, conduct, analyse and evaluate primary and secondary investigations into uniform circular motion, projectile motion, satellite motion and gravitational and electromagnetic phenomena, and to communicate methods and findings using appropriate conventions
- evaluate claims about motion and electromagnetism phenomena and associated technologies, and justify ssessments with reference to evidence and ethical considerations

Content descriptions

Science Inquiry Skills (Physics Unit 3)

- 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; consider research ethics
- Conduct investigations, including using force measurers, projectile launchers, electromagnets, transformers, electric motors and generators, safely, competently and methodically for accurate and reliable collection of data
- Represent data in meaningful and useful ways, including the use of appropriate SI units and symbols to indicate the accuracy of individual and multiple measurements; organise and analyse data to identify trends, patterns and relationships; identify uncertainty and limitations in data; select, synthesise and use evidence to make and justify conclusions
- Evaluate processes, claims and conclusions by considering the quality of available evidence; 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
  To view the mathematical representations related to this unit, CLICK HERE
- Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, text types and modes, including scientific reports

Field models - gravity and motion

Science Understanding

- A field model is used to explain the force applied by one mass on another mass that acts at a distance between the masses
- A change in position in a gravitational field that results in a change in potential energy requires work to be done on or by the field
- Newton's Law of Universal Gravitation states that the gravitational force between two masses is proportional to the product of their masses and inversely proportional to the square of the distance between their centres

- Gravitational field strength is defined as the net force per unit mass at a particular point in the field
- Acceleration due to gravity varies across the surface of Earth because Earth is not a sphere of uniform density
- 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 by treating the horizontal and vertical components of the motion independently because all inertial frames are equivalent
- When an object experiences a net force of constant magnitude perpendicular to its motion, it will undergo uniform circular motion
- Newton's Law of Universal Gravitation is used to explain the motion of planets and other satellites, modelled as uniform circular motion
- The rotational motion of Earth is used to minimise the energy required to place satellites in orbits
- To calculate the escape velocity for any object, the total energy of the object is required to be zero at infinity

Science as a Human Endeavour

- Scientists' use of new technologies in concert with established principles can result in the development of new models and theories (for example, Halley, Hooke and Newton used the Copernican principle and improved astronomical data resulting from advances in optical technology to explain both terrestrial motion and planetary and comet motion in terms of the 'action-at-a-distance' gravitational force)
- The accurate prediction of trajectories is important as it informs decisions and enables application of decisions in a range of contexts, (for example, improvements in individuals' sporting performance, use of forensic ballistics in law)

Field models - electromagnetism

Science Understanding

- The only forces that can act on scales greater than that of the atomic nucleus are gravity and electromagnetism
- The electromagnetic field model assumes that all charges are surrounded by an electric field and that moving charges are surrounded by an electric and a magnetic field
- Coulomb's Law states that the magnitude of the force between charges is proportional to the product of the charges and inversely proportional to the square of the distance between the charges

- A positively charged body placed in an electric field will experience a force in the direction of the field and a negatively charged body will experience a force in the opposite direction of the field; the strength of the electric field is defined as the force per unit charge
- When a charged body moves in an electric field, and its potential energy changes, work is done on or by the field
- The magnetic field model states that all moving charges produce a magnetic field that exerts a force on magnets, magnetic materials, moving charges and current-carrying wires placed in the field; the strength of the magnetic field is defined by the expression for the magnetic force acting on a current-carrying wire
- Moving charges and current-carrying wires experience a force in a magnetic field: this force is used in DC motors to produce torque
- Magnetic flux is defined in terms of magnetic field strength and area; a changing magnetic flux induces an electromotive force on charge in a conductor, which is used to produce a potential difference: this force is used in transformers to step up and step down potential differences and in AC induction motors to produce a torque
- Conservation of energy, expressed as Lenz's Law of electromagnetic induction, is used to determine the direction of induced current
- The efficiency of electromagnetic devices is improved by using ferromagnetic materials to intensify and confine the magnetic field
- Accelerating charges produce changing electric and magnetic fields whose propagation away from the accelerating charges is modelled as electromagnetic waves
- Electromagnetic waves are modelled as transverse waves made up of mutually perpendicular, changing electric and magnetic fields
- Oscillating charges produce electromagnetic waves of the same frequency as the oscillation; electromagnetic waves cause charges to oscillate with the frequency of the wave

Science as a Human Endeavour

- Models may have strong explanatory power, but require supporting experimental evidence before they are accepted by the scientific community (for example, Faraday's speculations and Maxwell's mathematical model of electromagnetic waves were not accepted until Hertz verified the existence of electromagnetic waves experimentally)
- Community support, and national and international funding and cooperation are necessary to build and operate large-scale scientific instruments (for example, the Large Hadron Collider, the Australian Synchrotron)
- Electromagnetic induction is utilised in a range of technologies including transformers, generators, large scale alternating current power distribution systems, induction motors, induction hot plates and microwave ovens; investment in development of these technologies is informed by health, environmental and commercial agendas

Mathematical representations and relationships (Physics Unit 3)

All measurement units are Système International (SI), unless otherwise specified.

Important constants used in algebraic representations are expressed in scientific notation.

Field models - gravity and motion

- $w = mg$

  w = weight force, m = mass, g = acceleration due to gravity (gravitational field strength)

- $F = \frac{GMm}{r^2}$ and $g = \frac{F}{m} = \frac{GM}{r^2}$

  F = gravitational force, G = universal constant of gravitation (6.67 x 10^{-11} N m^2 kg^{2}), M = mass of first body, m = mass of second body, r = separation between the centres of mass of the two bodies, g = acceleration due to gravity

- $v_y = gt + u_y$, $y = ½\, gt^2 + u_y t$, $v_y{}^2 = 2gy + u_y{}^2$, $v_x = u_x$ and $x = u_x t$

  y = vertical displacement, x = horizontal displacement, u_y = initial vertical velocity, v_y = vertical velocity at time t, u_x = initial horizontal velocity, v_x = horizontal velocity at time t, g = acceleration due to gravity, t = time into flight

- $v = \frac{2\pi r}{T}$

  v = tangential velocity, T = period

- $a_c = \frac{v^2}{r}$

  a_c = centripetal acceleration, v = tangential velocity, r = radius of the circle

- $F_{net} = \frac{mv^2}{r}$

  F_{net} = net force, m = mass of body undergoing uniform circular motion, v = tangential velocity, r = radius of the circle

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

  T = period of satellite, M = mass of the central body, r = orbital radius, G = universal constant of gravitation (6.67 x 10^{-11} N m^2 kg^{-2})

- $GPE = -\frac{GMm}{r}$

GPE = gravitational potential energy, G = universal constant of gravitation (6.67 x 10^{-11} N m^2 kg^{-2}), M = mass of first body, m = mass of second body, r = separation between the centres of mass of the two bodies

- $v_{esc} = \sqrt{\frac{2GM}{r}}$

  v_{esc} = minimum velocity needed to escape the planet's gravitational field, G = universal constant of gravitation (6.67 x 10^{-11} N m^2 kg^{-2}), M = mass of planet, r = separation between the centres of mass of the two bodies

Field models - electromagnetism

- $F = K_e \frac{qQ}{r^2}$

  F = force, K_e = Coulomb constant (9 x 10^9 N m^2 C^{-2}), q = charge on the first object, Q = charge on the second object, r = charge separation

- $E = \frac{F}{q} = \frac{K_e q}{r^2}$

  E = electric field strength, F = force, q = charge, r = charge separation, K_e = Coulomb constant (9 x 10^9 N m^2 C^{-2})

- $V = \frac{\Delta U}{q}$

  V = electrical potential difference, ΔU = change in potential energy, q = charge

- $B = \frac{K_m I}{r}$

  B = magnetic field strength, I = current in wire, r = distance from the centre of the wire, K_m = magnetic constant (2 x 10^{-7} T A^{-1} m)

- $B = \frac{F}{Il_\perp}$

  B = strength of applied magnetic field, F = force on a current element, $Il_\perp$ = component of the current element perpendicular to the applied magnetic field

- $F = qv_\perp B$

  F = force on a charge moving in an applied magnetic field, q = charge, $v_\perp$ = component of velocity perpendicular to the applied magnetic field, B = strength of applied magnetic field

- $\tau = nBIAcos\theta$

  τ = torque on a coil in an applied magnetic field, A = area of the coil, n = number of windings on the coil, I = current in the coil, θ = the angle between the plane of the coil and the applied magnetic field, B = strength of the applied magnetic field

- $\phi = BA_{\perp}$

  ϕ = magnetic flux density, $A_{\perp}$ = area of current loop perpendicular to the applied magnetic field, B = strength of applied magnetic field

- $emf = -\frac{n\Delta(BA_{\perp})}{\Delta t} = -n\frac{\Delta\phi}{\Delta t}$

  emf = induced potential difference, $\Delta\phi$ = change in magnetic flux density, n = number of windings in the loop, $A_{\perp}$ = area of current loop perpendicular to the applied magnetic field, Δt = change in time, B = strength of applied magnetic field

- $\frac{V_p}{V_s} = \frac{n_p}{n_s}$

  V_p = potential difference across the primary coil, V_s = potential difference across the secondary coil, n_p = number of turns on primary coil, n_s = number of turns on secondary coil

- $I_pV_p = I_sV_s$

  I_p = current in primary coil, V_p = potential difference across primary coil, I_s = current in secondary coil, V_s = potential difference across secondary coil

Unit 4: Current Models of Space-Time, Energy and Matter

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 new technologies that revolutionised the storage, processing and communication of information. In this unit, students extend their understanding of how existing theories are refined and new models and theories are developed.

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 explore the failure of the Aether model to satisfactorily explain electromagnetic wave propagation and the revolutionary theory proposed by Einstein, which overcame the shortcomings of the Aether model.

Students examine black body radiation and the photoelectric effect and investigate the quantum hypothesis developed by Planck and Einstein to explain these phenomena. They evaluate the contribution of the quantum model of light to the development of the quantum model of the atom and examine the Standard Model of particle physics and the Big Bang theory.

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 including 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
- understand how the Standard Model of particle physics explains the nature and interaction between the fundamental particles of matter
- understand how shortcomings in existing theories led to the development of the special theory of relativity and the quantum theory of light and matter, and how these theories have led to the development of technologies including lasers and photovoltaic and photonics devices
- use algebraic and graphical models to solve problems and make predictions related to the theory and applications of special relativity, black body radiation and the photoelectric effect, light quanta and wave particle duality, the Bohr model of the atom, fundamental particles, and simple particle accelerators
- 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 findings using appropriate conventions
- 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.

Content descriptions

Science Inquiry Skills (Physics Unit 4)

- 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; consider research ethics
- Conduct investigations, including using objects for heating and using radioactive sources, spectrometers, spectral and incandescent light sources, lasers, LEDs and photovoltaic devices, safely, competently and methodically for accurate and reliable collection of data
- Represent data in meaningful and useful ways including the use of appropriate SI units and symbols to indicate the accuracy of individual and multiple measurements; organise and analyse data to identify trends, patterns and relationships; identify uncertainty and limitations in data; select, synthesise and use evidence to make and justify conclusions
- Evaluate processes, claims and conclusions by considering the quality of available evidence; use reasoning to construct scientific arguments
- Select, construct and use appropriate representations, including text and graphic representations of empirical and theoretical relationships, flow diagrams and atomic energy level diagram, 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
  To view the mathematical representations related to this unit, CLICK HERE
- Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, text types and modes, including scientific reports

The Theory of Relativity

Science Understanding

- At speeds approaching the speed of light, Newtonian physics no longer accurately predicts motion and interactions
- Einstein's theory of relativity postulates that the speed of light is an absolute constant and that all inertial reference frames are equivalent; it is used to explain motion and interactions at speeds approaching the speed of light
- A consequence of Einstein's postulates is that Newton's assumption of an absolute rest frame is not valid; simultaneity, mass, length and time become relative rather than absolute quantities that depend on the observer's frame of reference

- Because the speed of light in a vacuum is the limiting speed for material bodies but the momentum and kinetic energy of material bodies is not limited, mass and energy must be equivalent quantities (that is, mass is a form of energy)
- Work on non-inertial frames led Einstein to suggest light is deflected when it passes near massive objects because space and time are affected by gravitational fields

Science as a Human Endeavour

- Development of new theories and models by individuals or teams often builds on existing research, and can require the research of other scientists to support them before they are accepted by the scientific community (for example, Einstein's special theory of relativity arose from investigation of Maxwell's equations, which challenged the accepted Aether model of electromagnetic wave propagation, explained the null result of the Michelson-Morley experiment and made controversial predictions that were verified by subsequent experiments)
- Applications of special relativity include GPS tracking systems; increasing use and availability of these systems has significant social implications (for individuals, industry, government, and security organisations)

The Quantum Model

Science Understanding

- The behaviour of subatomic particles and the interaction of light with matter on the atomic scale cannot be adequately explained by Newtonian physics or electromagnetic wave theory
- Quantum theory, which postulates the quantisation of light, is used to explain black body radiation, the photoelectric effect and interactions between electromagnetic radiation and matter
- The current model of the atom is based on the quantisation of electron energy states and is used to explain atomic emission and absorption spectra
- Molecular absorption and emission of photons influences the temperature of the atmosphere and contributes to the greenhouse effect
- Wave-particle duality imposes a quantifiable limit to the accuracy with which measurements of sub-atomic phenomena can be made, and to the accuracy to which events can be predicted by quantum theory
- Quantum theory is used to explain phenomena at the subatomic level and predicts that, on this scale, the act of observation can influence experimental outcomes

Science as a Human Endeavour

- Development of new models and theories often requires integration of evidence from a wide range of previous studies across multiple fields (for example, Planck, Bohr and Einstein integrated evidence from studies of heat radiation, spectroscopy and the photoelectric effect to develop the photon model, which contradicted both the electromagnetic wave model and the particle model)
- Acceptance of new models and theories can occur when the new model or theory can be shown to explain a greater range of phenomena (for example, the acceptance of the Bohr model over the models of Thomson and Rutherford; the acceptance of photon model of light over the electromagnetic wave model; the acceptance the probabilistic nature of quantum theory over the determinism of Newtonian physics)
- The use of devices developed from the application of quantum physics, including the laser, photovoltaic cells and microprocessors, have significantly changed many aspects of society (for example, access to information, medical diagnosis and treatments, global energy systems and environmental monitoring)

The Standard Model

Science Understanding

- The Standard Model of particle physics explains the interactions between all the known fundamental particles by combining the quantum field theories of three of the four fundamental forces in a single theoretical framework
- The Standard Model is based on three types of fundamental particles: quarks that experience the strong nuclear force, leptons that do not experience the strong nuclear force, and gauge bosons that mediate the forces between particles
- High-energy particle accelerators are used to test the predictions of the Standard Model
- The Big Bang theory uses the Standard Model to describe and explain the evolution of the four fundamental forces and the production of matter
- The Standard Model is not a complete theory of fundamental particles and their interactions because it does not include gravity
- Some aspects of the observed universe cannot be explained by the Big Bang theory or the Standard Model of particle physics

Science as a Human Endeavour

- Approaches to scientific inquiry have changed over time and frame current research (for example, reductionism and unification continue to be guiding principles for physicists searching for ‘fundamental particles’, which may or may not exist, within Grand Unified Theories and Theories of Everything)
- The pursuit of knowledge about fundamental processes of the universe requires significant human and material resources (for example, large particle accelerators and telescopes); this necessitates prioritising finite resources, coordinating large teams of scientists and international cooperation

Mathematical representations and relationships (Physics Unit 4)

All measurement units are Système International (SI), unless otherwise specified.

Important constants used in algebraic representations are expressed in scientific notation.

The Theory of Relativity

- $t = \frac{t_o}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$

  t = *time interval in the moving frame as measured by the observer in the proper frame,* t_o = *proper time interval (time interval for a clock at rest in the observer's frame),* v = *relative speed of the two inertial frames,* c = *speed of light in a vacuum (3 x 10⁸ m s⁻¹)*

- $l = l_o\sqrt{\left(1-\frac{v^2}{c^2}\right)}$

  l = *length interval in the frame moving at velocity* (v) *with respect to the observer,* l_o = *proper length (length in a frame at rest with respect to the observer),* c = *speed of light (3 x 10⁸ m s⁻¹)*

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

  m = *corrected mass for an object moving with velocity* (v) *with respect to the observer,* m_o = *rest mass,* c = *speed of light (3 x 10⁸ m s⁻¹)*

- $\Delta E = \Delta mc^2$

  ΔE = *change in energy,* Δm = *change in mass,* c = *speed of light (3 x 10⁸ m s⁻¹)*

The Quantum Model

- $E = hf$

  E = *energy of photon,* f = *frequency,* h = *Planck's constant (6.626 x 10⁻³⁴ J s)*

- $\lambda_{max} = \frac{b}{T}$

  λ_{max} = *wavelength of maximum emission,* T = *absolute temperature,* b = *Wien's displacement constant (2.898 x 10⁻³ m K)*

- $\frac{P}{A} = \sigma T^4$

$\frac{P}{A}$ = *power radiated per unit surface area,* T = *absolute temperature,* σ = *Stefan's constant (5. 67 x* 10^{-8} *J w* m^{-2} K^{-4}*)*

- $KE = hf - W$

  KE = *kinetic energy of photoelectron,* hf = *energy of incident photon,*
  W = *work function of the material*

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

  λ = *wavelength associated with particle,* m = *mass of particle travelling with velocity (*v*),* p = *momentum of particle,* h = *Planck's constant (6.626 x* 10^{-34} *J s)*

- $n\lambda = 2\pi r$

  n = *an integer 1, 2, 3, 4… ,* λ = *wavelength of electron,* r = *orbital radius of electron*

- $mvr = \frac{nh}{2\pi}$

  m = *mass of electron,* v = *velocity of electron,* r = *orbital radius of electron,*
  n = *an integer 1, 2, 3, 4, etc.,* h = *Planck's constant (6.626 x* 10^{-34} *J s)*

- $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

  λ = *wavelength of spectral line,* n_i = *principle quantum number of initial electron state,* n_f = *principle quantum number of final electron state,* R = *Rydberg's constant (1.097 x* 10^{7} m^{-1}*)*

- $\Delta p \Delta x \geq \frac{h}{2\pi}$

  Δp = *uncertainty in momentum,* Δx = *uncertainty in position,* h = *Planck's constant (6.626 x* 10^{-34} *J s)*

- $\Delta E \Delta t \geq \frac{h}{2\pi}$

  ΔE = *uncertainty in energy,* Δt = *uncertainty in time,* h = *Planck's constant (6.626 x* 10^{-34} *J s)*

Achievement Standard Unit 3 and 4

	Physics Concepts, Models and Applications	Physics Inquiry Skills
A	For the physical systems studied, the student: • analyses the relationships between components and properties of physical systems qualitatively and quantitatively • analyses energy transfers and transformations in physical phenomena and associated technologies qualitatively and quantitatively • evaluates the theories and models used to describe physical systems and processes; the supporting evidence, the phenomena they can be applied to, their limitations and assumptions • selects, applies and where appropriate, combines, theories and models to make plausible predictions, explain new phenomena and solve complex problems For the physical science contexts studied, the student: • evaluates the origins and significance of key findings and the role of technologies, debate and review in the development and application of concepts, theories and models • evaluates how physics has been used in concert with other sciences to meet diverse needs and inform decision making; and the social, economic and ethical implications of these applications	The student competently and independently • utilises secondary sources to design and conduct safe, ethical investigations to collect valid, reliable data in response to a specific question, hypothesis or problem • analyses data sets to identify and evaluate causal and correlational relationships between variables • represents data accurately, justifies their selection of data as evidence and develops evidence-based conclusions • evaluates processes and claims; provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to communicate understanding, solve complex problems and make plausible predictions • communicates clearly and accurately in a wide range of modes, styles and genres (including scientific reports) for specific audiences and purposes

B	For the physical systems studied, the student: • explains the relationships between components and properties of physical systems qualitatively and quantitatively • explains energy transfers and transformations in physical phenomena and associated technologies qualitatively and quantitatively • explains the theories and models used to describe physical systems and processes; the phenomena they can be applied to, and their limitations • applies laws, theories and models of physical systems and processes to make plausible predictions, explain phenomena and solve problems For the physical science contexts studied, the student: • explains the origins and significance of key findings and the role of technologies, debate and review in the development of concepts, laws, theories and models • explains how physics has been used to meet diverse needs and inform decision making; and the social, economic and ethical implications of these applications	The student competently and independently • designs and conducts safe, ethical investigations to collect valid, reliable data in response to a specific question, hypothesis or problem • analyses data sets to identify causal and correlational relationships between variables • represents data accurately, selects data as evidence and provides evidence for conclusions • evaluates processes and claims; provides a critique with reference to evidence and identifies possible improvements or alternatives • selects, constructs and uses appropriate representations to communicate ideas, solve problems and make predictions • communicates clearly and accurately in a range of modes, styles and genres (including scientific reports) for specific audiences and purposes
C	For the physical systems studied, the student: • describes the relationships between components and properties of physical systems qualitatively • describes energy transfers and transformations in physical phenomena and associated technologies qualitatively • describes key aspects of the theories and models used to describe physical systems • applies a theory or model of a physical system to explain phenomena or solve a problem For the physical science contexts studied, the student: • describes key findings and the role of technologies and review in the development of concepts, theories and models • describes how physics has been used to meet needs and inform decision making; and some implications of these applications	The student competently and independently • designs and conducts safe, ethical investigations which enable collection of valid data in response to a specific question, hypothesis or problem • analyses data to identify relationships between variables • selects and represents data to demonstrate relationships and constructs conclusions based on data • assesses processes and claims and suggests improvements or alternatives • selects and uses appropriate representations to communicate ideas, solve problems and make predictions • communicates accurately in a range of modes, styles and genres (including scientific reports) for specific purposes

D	For the physical systems studied, the student: • describes how components of physical systems are related • describes the properties of physical systems and how they are affected by change • describes the laws used to describe physical processes or relationships • uses understanding of physical processes and relationships to explain aspects of phenomena For the physical science contexts studied, the student: • identifies that physics ideas have changed over time and that science ideas are communicated within the science community • describes ways in which physics has been used in society to meet needs	The student competently and independently • designs and conducts safe, ethical investigations which enable collection of data in response to a specific question, hypothesis or problem • analyses data to identify cause and effect relationships • selects and represents data and presents simple conclusions based on data • considers processes and claims from a personal perspective • communicates using key representations in a range of modes and genres (including scientific reports)
E	For the physical systems studied, the student: • describes observable physical phenomena and processes • describes how observable properties physical systems are measured • uses understanding of cause and effect to describe changes to physical systems For the physical science contexts studied, the student: • identifies that ideas have changed over time • describes ways in which physics has been used in society	The student competently and independently • conducts safe, ethical investigations which enable collection of data • identifies trends in data and presents conclusions • considers claims from a personal perspective • communicates in a range of modes and genres

Glossary

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.

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.

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 (see separate entries for the distinctions between primary and secondary data.

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.

Environment

All the surroundings, both living and non-living.

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.

Fundamental forces

Four fundamental forces have been identified, that interact with all matter in the universe. They are, in order from strongest to weakest, the strong, electromagnetic, weak and gravity forces.

Hypothesis

A tentative idea, based on observation, that can be supported or refuted by experiment.

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.

Law

Statement of a relationship based on available evidence

Local environment

Surroundings that can be considered as proximal or familiar to the subject of investigation (for example, an organism, mountain, student).

Material

A substance with particular qualities or that is used for specific purposes.

Matter

A physical substance; anything that has mass and occupies space.

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"

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 source

In science, a primary source is 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.

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.

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.

Research

To locate, gather, record and analyse information in order to develop understanding.

Scientific language

Terminology that has specific meaning in a scientific context.

Secondary source

Information that has been compiled from records of primary sources by a person or persons not directly involved in the primary event.

Simulation

A representation of a process, event or system which imitates the real 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.

Technology

The development of products, services, systems and environments, using various types of knowledge, to meet human needs and wants.

Theory

An explanation of a set of observations that is based on one or more proven hypotheses which has been accepted through consensus by a group of scientists.

Thought experiments

A process whereby the consequences of a principle, postulate or theory are examined without necessarily undertaking the experiment.

Trend

General direction in which something is changing.

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.