The Australian Curriculum

Subjects	Biology, Chemistry, Earth and Environmental Science and Physics
Units	Unit 1, Unit 2, Unit 3 and Unit 4
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AUSTRALIAN CURRICULUM, ASSESSMENT AND REPORTING AUTHORITY

Table of Contents

The Australian Curriculum
Biology

Biology

Rationale and Aims

Rationale

Biology is the study of the fascinating diversity of life as it has evolved and as it interacts and functions. Investigation of biological systems and their interactions, from cellular processes to ecosystem dynamics, has led to biological knowledge and understanding that enable us to explore and explain everyday observations, find solutions to biological issues, and understand the processes of biological continuity and change over time.

Living systems are all interconnected and interact at a variety of spatial and temporal scales, from the molecular level to the ecosystem level. Investigation of living systems involves classification of key components within the system, and analysis of how those components interact, particularly with regard to the movement of matter and the transfer and transformation of energy within and between systems. Analysis of the ways living systems change over time involves understanding of the factors that impact the system, and investigation of system mechanisms to respond to internal and external changes and ensure continuity of the system. The theory of evolution by natural selection is critical to explaining these patterns and processes in biology, and underpins the study of all living systems.

Australian, regional and global communities rely on the biological sciences to understand, address and successfully manage environmental, health and sustainability challenges facing society in the twenty-first century. These include the biosecurity and resilience of ecosystems, the health and wellbeing of humans and other organisms and their populations, and the sustainability of biological resources. Students use their understanding of the interconnectedness of biological systems when evaluating both the impact of human activity and the strategies proposed to address major biological challenges now and in the future in local, national and global contexts.

This subject explores ways in which scientists work collaboratively and individually in a range of integrated fields to increase understanding of an ever-expanding body of biological knowledge. Students develop their investigative, analytical and communication skills through field, laboratory and research investigations of living systems and through critical evaluation of the development, ethics, applications and influences of contemporary biological knowledge in a range of contexts.

Studying Senior Secondary Science provides students with a suite of skills and understandings that are valuable to a wide range of further study pathways and careers. Understanding of biological concepts, as well as general science knowledge and skills, is relevant to a range of careers, including those in medical, veterinary, food and marine sciences, agriculture, biotechnology, environmental rehabilitation, biosecurity, quarantine, conservation and eco-tourism. This subject will also provide a foundation for students to critically consider and to make informed decisions about contemporary biological issues in their everyday lives.

Aims

Biology aims to develop students':

- sense of wonder and curiosity about life and respect for all living things and the environment
- understanding of how biological systems interact and are interrelated; the flow of matter and energy through and between these systems; and the processes by which they persist and change
- understanding of major biological concepts, theories and models related to biological systems at all scales, from subcellular processes to ecosystem dynamics
- appreciation of how biological knowledge has developed over time and continues to develop; how scientists use biology in a wide range of applications; and how biological knowledge influences society in local, regional and global contexts

- ability to plan and carry out fieldwork, laboratory and other research investigations including the collection and analysis of qualitative and quantitative data and the interpretation of evidence
- ability to use sound, evidence-based arguments creatively and analytically when evaluating claims and applying biological knowledge
- ability to communicate biological understanding, findings, arguments and conclusions using appropriate representations, modes and genres.

Organisation

Overview of senior secondary Australian Curriculum

ACARA has developed senior secondary Australian Curriculum for English, Mathematics, Science and History according to a set of design specifications. The ACARA Board approved these specifications following consultation with state and territory curriculum, assessment and certification authorities.

The senior secondary Australian Curriculum specifies 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) expected of 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 and examinations). 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 their courses. They 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 local courses that integrate the Australian Curriculum content and achievement standards and any additional information, guidelines and rules to satisfy local requirements including advice on entry and exit points and credit for completed study.

The senior secondary Australian Curriculum for each subject should not, therefore, be read as a course of study. Rather, it is presented as content and achievement standards for integration into state and territory courses.

Senior secondary Science subjects

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

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

Structure of Biology

Units

In Biology, students develop their understanding of biological systems, the components of these systems and their interactions, how matter flows and energy is transferred and transformed in these systems, and the ways in which these systems are affected by change at different spatial and temporal scales. There are four units:

- Unit 1: Biodiversity and the interconnectedness of life
- Unit 2: Cells and multicellular organisms
- Unit 3: Heredity and continuity of life
- Unit 4: Maintaining the internal environment.

In Units 1 and 2, students build on prior learning to develop their understanding of relationships between structure and function in a range of biological systems, from ecosystems to single cells and multicellular organisms. In Unit 1, students analyse abiotic and biotic ecosystem components and their interactions, using classification systems for data collection, comparison and evaluation. In Unit 2, students investigate the interdependent components of the cell system and the multiple interacting systems in multicellular organisms.

In Units 3 and 4, students examine the continuity of biological systems and how they change over time in response to external factors. They examine and connect system interactions at the molecular level to system change at the organism and population levels. In Unit 3, students investigate mechanisms of heredity and the ways in which inheritance patterns can be explained, modelled and predicted; they connect these patterns to population dynamics and apply the theory of evolution by natural selection in order to examine changes in populations. In Unit 4, students investigate system change and continuity in response to changing external conditions and pathogens; they investigate homeostasis and the transmission and impact of infectious disease at cellular and organism levels; and they consider the factors that encourage or reduce the spread of infectious disease at the population level.

Each unit includes:

- Unit descriptions – short descriptions of the purpose of and rationale for each unit
- Learning outcomes – six to eight statements describing the learning expected as a result of studying the unit
- Content descriptions – descriptions of the core content to be taught and learned, organised into three strands:
  - *Science Inquiry Skills*
  - *Science as a Human Endeavour*
  - *Science Understanding (organised in sub-units).*

Organisation of content

Science strand descriptions

The Australian Curriculum: Science has three interrelated strands: *Science Inquiry Skills, Science as a Human Endeavour* and *Science Understanding*. These strands are used to organise the Science learning area from Foundation to Year 12. In the senior secondary Science subjects, the three strands build on students' learning in the F-10 Australian Curriculum: Science.

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. Students' experiences of school science should mirror 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 for *Science Inquiry Skills*, *Science as a Human Endeavour* and *Science Understanding* have been written so that this integration is possible in each unit.

Science Inquiry Skills

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

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

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

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 more specific skills to be taught within the 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:

- Identifying, researching and constructing questions for investigation; proposing hypotheses; and predicting possible outcomes
- Designing investigations, including the procedure/s 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
- Conducting investigations, including using equipment and techniques safely, competently and methodically for the collection of valid and reliable data
- Representing data in meaningful and useful ways; organising and analysing data to identify trends, patterns and relationships; recognising error, uncertainty and limitations in data; and selecting, synthesising and using evidence to construct and justify conclusions
- Interpreting scientific and media texts and evaluating processes, claims and conclusions by considering the quality of available evidence; and using reasoning to construct scientific arguments
- Selecting, constructing and using appropriate representations to communicate understanding, solve problems and make predictions
- Communicating to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes.

The senior secondary Science subjects have been designed to accommodate, if appropriate, an extended scientific investigation within 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.

Science as a Human Endeavour

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

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

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

Across the senior secondary Science subjects, the same set of *Science as a Human Endeavour* content descriptions is used for Units 1 and 2 of the subjects; and another set for Units 3 and 4. This consistent approach enables students to develop a rich appreciation of the complex ways in which science interacts with society, through the exploration of *Science as a Human Endeavour* concepts across the subjects and in multiple contexts.

'Examples in context' will be developed to illustrate possible contexts related to *Science Understanding* content, in which students could explore *Science as a Human Endeavour* concepts. These will be made available to complement the final online curriculum. Each *Example in context* will be aligned to the relevant sub-unit in *Science Understanding* and will include links to the relevant *Science as a Human Endeavour* content descriptions.

Science Understanding

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

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

Science Understanding can be developed through the selection of contexts that have relevance to and are engaging for students. The Australian Curriculum: Science has been designed to provide jurisdictions, schools and teachers with the flexibility to select contexts that meet the social, geographic and learning needs of their students.

Organisation of achievement standards

The Biology achievement standards are organised by two dimensions: 'Biology Concepts, Models and Applications', and 'Biology Inquiry Skills'. They describe five levels of student achievement.

'Biology 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. 'Biology Inquiry Skills' describes the skills students demonstrate when investigating the content developed through the strands of *Science Understanding* and *Science as a Human Endeavour*.

Senior secondary achievement standards have been written for each Australian Curriculum senior secondary subject. The achievement standards provide an indication of typical performance at five different levels (corresponding to grades A to E) following the completion of study of senior secondary Australian Curriculum content for a pair of units. They are broad statements of understanding and skills that are best read and understood in conjunction with the relevant unit content. They are structured to reflect key dimensions of the content of the relevant learning area. They will be eventually accompanied by illustrative and annotated samples of student work/ performance/ responses.

The achievement standards will be refined empirically through an analysis of samples of student work and responses to assessment tasks: they cannot be maintained *a priori* without reference to actual student performance. Inferences can be drawn about the quality of student learning on the basis of observable differences in the extent, complexity, sophistication and generality of the understanding and skills typically demonstrated by students in response to well-designed assessment activities and tasks.

In the short term, achievement standards will inform assessment processes used by curriculum, assessment and certifying authorities for course offerings based on senior secondary Australian Curriculum content.

ACARA has made reference to a common syntax (as a guide, not a rule) in constructing the achievement standards across the learning areas. The common syntax that has guided development is as follows:

- Given a specified context (as described in the curriculum content)
- With a defined level of consistency/accuracy (the assumption that each level describes what the student does well, competently, independently, consistently)
- Students perform a specified action (described through a verb)
- In relation to what is valued in the curriculum (specified as the object or subject)
- With a defined degree of sophistication, difficulty, complexity (described as an indication of quality)

Terms such as 'analyse' and 'describe' have been used to specify particular action but these can have everyday meanings that are quite general. ACARA has therefore associated these terms with specific meanings that are defined in the senior secondary achievement standards glossary and used precisely and consistently across subject areas.

Links to Foundation to Year 10

Progression from the F-10 Australian Curriculum: Science

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

In particular, the Biology curriculum continues to develop the key concepts introduced in the Biological Sciences sub-strand, that is, that a diverse range of living things have evolved on Earth over hundreds of millions of years, that living things are interdependent and interact with each other and their environment, and that the form and features of living things are related to the functions their systems perform.

Mathematical skills expected of students studying Biology

The Biology 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 scientific arguments, claims or conclusions. In gathering and recording numerical data, students are required to make measurements using appropriate units to an appropriate degree of accuracy.

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

It is assumed that students will be able to competently:

- perform calculations involving addition, subtraction, multiplication and division of quantities
- perform approximate evaluations of numerical expressions
- express fractions as percentages, and percentages as fractions
- calculate percentages
- recognise and use ratios
- transform decimal notation to power of ten notation
- substitute physical quantities into an equation using consistent units so as to calculate one quantity and check the dimensional consistency of such calculations
- solve simple algebraic equations
- comprehend and use the symbols/notations $<, >, \Delta, \approx$
- translate information between graphical, numerical and algebraic forms
- distinguish between discrete and continuous data then select appropriate forms, variables and scales for constructing graphs
- construct and interpret frequency tables and diagrams, pie charts and histograms
- describe and compare data sets using mean, median and inter-quartile range
- interpret the slope of a linear graph.

Representation of General capabilities

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

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

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

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

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

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

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

Representation of Cross-curriculum Priorities

While the significance of the cross-curriculum priorities for Biology varies, there are opportunities for teachers to select contexts that incorporate the key concepts from each priority.

Through an investigation of contexts that draw on *Aboriginal and Torres Strait Islander histories and cultures* students could investigate the importance of Aboriginal and Torres Strait Islander Peoples' knowledge in developing a richer understanding of the Australian environment. Students could develop an appreciation of the unique Australian biota and its interactions, the impacts of Aboriginal and Torres Strait Islander Peoples on their environments and the ways in which the Australian landscape has changed over tens of thousands of years. They could examine the ways in which Aboriginal and Torres Strait Islander knowledge of ecosystems has developed over time and the spiritual significance of Country/Place.

Contexts that draw on Asian scientific research and development and collaborative endeavours in the Asia Pacific region provide an opportunity for students to investigate *Asia and Australia's engagement with Asia*. Students could explore the diverse environments of the Asia region and develop an appreciation that interaction between human activity and these environments continues to influence the region, including Australia, and has significance for the rest of the world. By examining developments in biological science, students could appreciate that the Asia region plays an important role in scientific research and development, including through collaboration with Australian scientists, in such areas as medicine, natural resource management, biosecurity and food security.

The *Sustainability* cross-curriculum priority is explicitly addressed in the Biology curriculum. Biology provides authentic contexts for exploring, investigating and understanding the function and interactions of biotic and abiotic systems across a range of spatial and temporal scales. By investigating the relationships between biological systems and system components, and how systems respond to change, students develop an appreciation for the interconnectedness of the biosphere. Students appreciate that biological science provides the basis for decision making in many areas of society and that these decisions can impact 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 and provide for a more sustainable future.

Safety

Science learning experiences may involve the use of potentially hazardous substances and/or hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students and that school practices meet the requirements of the *Work Health and Safety Act 2011,* in addition to relevant state 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.

Animal ethics

Through a consideration of research ethics as part of *Science Inquiry Skills*, students will examine their own ethical position, draw on ethical perspectives when designing investigation methods, and ensure that any activities that impact on living organisms comply with the *Australian code of practice for the care and use of animals for scientific purposes 7th* edition (2004) (http://www.nhmrc.gov.au/guidelines/publications/ea16).

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*, in addition to relevant state or territory guidelines.

When state and territory curriculum authorities integrate the Australian Curriculum into local courses, they will include more specific advice on the care and use of, or interaction with, animals.

For further information about relevant guidelines or to access your local Animal Ethics Committee, contact your state or territory curriculum authority.

Unit 1: Biodiversity and the interconnectedness of life

Unit Description

The current view of the biosphere as a dynamic system composed of Earth's diverse, interrelated and interacting ecosystems developed from the work of eighteenth and nineteenth century naturalists, who collected, classified, measured and mapped the distribution of organisms and environments around the world. In this unit, students investigate and describe a number of diverse ecosystems, exploring the range of biotic and abiotic components to understand the dynamics, diversity and underlying unity of these systems.

Students develop an understanding of the processes involved in the movement of energy and matter in ecosystems. They investigate ecosystem dynamics, including interactions within and between species, and interactions between abiotic and biotic components of ecosystems. They also investigate how measurements of abiotic factors, population numbers and species diversity, and descriptions of species interactions, can form the basis for spatial and temporal comparisons between ecosystems. Students use classification keys to identify organisms, describe the biodiversity in ecosystems, investigate patterns in relationships between organisms, and aid scientific communication.

Through the investigation of appropriate contexts, students explore how international collaboration, evidence from multiple disciplines and the use of ICT and other technologies have contributed to the study and conservation of national, regional and global biodiversity. They investigate how scientific knowledge is used to offer valid explanations and reliable predictions, and the ways in which scientific knowledge interacts with social, economic, cultural and ethical factors.

Fieldwork is an important part of this unit, providing valuable opportunities for students to work together to collect first-hand data and to experience local ecosystem interactions. In order to understand the interconnectedness of organisms, the physical environment and human activity, students analyse and interpret data collected through investigation of a local environment and from sources relating to other Australian, regional and global environments.

Learning Outcomes

By the end of this unit, students:

- understand how classification helps to organise, analyse and communicate data about biodiversity
- understand that ecosystem diversity and dynamics can be described and compared with reference to biotic and abiotic components and their interactions
- understand how theories and models have developed based on evidence from multiple disciplines; and the uses and limitations of biological knowledge in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into biodiversity and flows of matter and energy in a range of ecosystems
- evaluate, with reference to empirical evidence, claims about relationships between and within species, diversity of and within ecosystems, and energy and matter flows
- communicate biological understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Biology Unit 1)

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSBL001)

Design investigations, including the procedure/s 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, including animal ethics (ACSBL002)

Conduct investigations, including using ecosystem surveying techniques, safely, competently and methodically for the collection of valid and reliable data (ACSBL003)

Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; qualitatively describe sources of measurement error, and uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSBL004)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSBL005)

Select, construct and use appropriate representations, including classification keys, food webs and biomass pyramids, to communicate conceptual understanding, solve problems and make predictions (ACSBL006)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSBL007)

Science as a Human Endeavour (Units 1 and 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSBL008)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL009)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL010)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSBL011)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL012)

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSBL013)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL014)

Science Understanding

Describing biodiversity

Biodiversity includes the diversity of species and ecosystems; measures of biodiversity rely on classification and are used to make comparisons across spatial and temporal scales (ACSBL015)

Biological classification is hierarchical and based on different levels of similarity of physical features, methods of reproduction and molecular sequences (ACSBL016)

Biological classification systems reflect evolutionary relatedness between groups of organisms (ACSBL017)

Most common definitions of species rely on morphological or genetic similarity or the ability to interbreed to produce fertile offspring in natural conditions – but, in all cases, exceptions are found (ACSBL018)

Ecosystems are diverse, composed of varied habitats and can be described in terms of their component species, species interactions and the abiotic factors that make up the environment (ACSBL019)

Relationships and interactions between species in ecosystems include predation, competition, symbiosis and disease (ACSBL020)

In addition to biotic factors, abiotic factors including climate and substrate can be used to describe and classify environments (ACSBL021)

Ecosystem dynamics

The biotic components of an ecosystem transfer and transform energy originating primarily from the sun to produce biomass, and interact with abiotic components to facilitate biogeochemical cycling, including carbon and nitrogen cycling; these interactions can be represented using food webs, biomass pyramids, water and nutrient cycles (ACSBL022)

Species or populations, including those of microorganisms, fill specific ecological niches; the competitive exclusion principle postulates that no two species can occupy the same niche in the same environment for an extended period of time (ACSBL023)

Keystone species play a critical role in maintaining the structure of the community; the impact of a reduction in numbers or the disappearance of keystone species on an ecosystem is greater than would be expected based on their relative abundance or total biomass (ACSBL024)

Ecosystems have carrying capacities that limit the number of organisms (within populations) they support, and can be impacted by changes to abiotic and biotic factors, including climatic events (ACSBL025)

Ecological succession involves changes in the populations of species present in a habitat; these changes impact the abiotic and biotic interactions in the community, which in turn influence further changes in the species present and their population size (ACSBL026)

Ecosystems can change dramatically over time; the fossil record and sedimentary rock characteristics provide evidence of past ecosystems and changes in biotic and abiotic components (ACSBL027)

Human activities (for example, over-exploitation, habitat destruction, monocultures, pollution) can reduce biodiversity and can impact on the magnitude, duration and speed of ecosystem change (ACSBL028)

Models of ecosystem interactions (for example, food webs, successional models) can be used to predict the impact of change and are based on interpretation of and extrapolation from sample data (for example, data derived from ecosystem surveying techniques); the reliability of the model is determined by the representativeness of the sampling (ACSBL029)

Biology

Unit 2: Cells and multicellular organisms

Unit Description

The cell is the basic unit of life. Although cell structure and function are very diverse, all cells possess some common features: all prokaryotic and eukaryotic cells need to exchange materials with their immediate external environment in order to maintain the chemical processes vital for cell functioning. In this unit, students examine inputs and outputs of cells to develop an understanding of the chemical nature of cellular systems, both structurally and functionally, and the processes required for cell survival. Students investigate the ways in which matter moves and energy is transformed and transferred in the biochemical processes of photosynthesis and respiration, and the role of enzymes in controlling biochemical systems.

Multicellular organisms typically consist of a number of interdependent systems of cells organised into tissues, organs and organ systems. Students examine the structure and function of plant and animal systems at cell and tissue levels in order to describe how they facilitate the efficient provision or removal of materials to and from all cells of the organism.

Through the investigation of appropriate contexts, students explore how international collaboration, evidence from multiple disciplines and the use of ICT and other technologies have contributed to developing understanding of the structure and function of cells and multicellular organisms. They investigate how scientific knowledge is used to offer valid explanations and reliable predictions, and the ways in which scientific knowledge interacts with social, economic, cultural and ethical factors.

Students use science inquiry skills to explore the relationship between structure and function, by conducting real or virtual dissections and carrying out microscopic examination of cells and tissues. Students consider the ethical considerations that apply to the use of living organisms in research. They develop skills in constructing and using models to describe and interpret data about the functions of cells and organisms.

Learning Outcomes

By the end of this unit, students:

- understand that the structure and function of cells and their components are related to the need to exchange matter and energy with their immediate environment
- understand that multicellular organisms consist of multiple interdependent and hierarchically-organised systems that enable exchange of matter and energy with their immediate environment
- understand how theories and models have developed based on evidence from multiple disciplines; and the uses and limitations of biological knowledge in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into the structure and function of cells and multicellular organisms
- evaluate, with reference to empirical evidence, claims about cellular processes and the structure and function of multicellular organisms
- communicate biological understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Biology Unit 2)

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSBL030)

Design investigations, including the procedure/s 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, including animal ethics (ACSBL031)

Conduct investigations, including microscopy techniques, real or virtual dissections and chemical analysis, safely, competently and methodically for the collection of valid and reliable data (ACSBL032)

Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; qualitatively describe sources of measurement error, and uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSBL033)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSBL034)

Select, construct and use appropriate representations, including diagrams of structures and processes; and images from different imaging techniques, to communicate conceptual understanding, solve problems and make predictions (ACSBL035)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSBL036)

Science as a Human Endeavour (Units 1 and 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSBL037)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSBL038)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSBL039)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSBL040)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSBL041)

Scientific knowledge can enable scientists to offer reliable explanations and make reliable predictions (ACSBL042)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL043)

Science Understanding

Cells as the basis of life

Cells require inputs of suitable forms of energy, including light energy or chemical energy in complex molecules, and matter, including gases, simple nutrients, ions, and removal of wastes, to survive (ACSBL044)

The cell membrane separates the cell from its surroundings and controls the exchange of materials, including gases, nutrients and wastes, between the cell and its environment (ACSBL045)

Movement of materials across membranes occurs via diffusion, osmosis, active transport and/or endocytosis (ACSBL046)

Factors that affect exchange of materials across membranes include the surface-area-to-volume ratio of the cell, concentration gradients, and the physical and chemical nature of the materials being exchanged (ACSBL047)

Prokaryotic and eukaryotic cells have many features in common, which is a reflection of their common evolutionary past, but prokaryotes lack internal membrane bound organelles, do not have a nucleus, are significantly smaller than eukaryotes, usually have a single circular chromosome, and exist as single cells (ACSBL048)

In eukaryotic cells, specialised organelles facilitate biochemical processes of photosynthesis, cellular respiration, the synthesis of complex molecules (including carbohydrates, proteins, lipids and other biomacromolecules), and the removal of cellular products and wastes (ACSBL049)

Biochemical processes in the cell are controlled by the nature and arrangement of internal membranes, the presence of specific enzymes, and environmental factors (ACSBL050)

Enzymes have specific functions, which can be affected by factors including temperature, pH, the presence of inhibitors, and the concentrations of reactants and products (ACSBL051)

Photosynthesis is a biochemical process that in plant cells occurs in the chloroplast and that uses light energy to synthesise organic compounds; the overall process can be represented as a balanced chemical equation (ACSBL052)

Cellular respiration is a biochemical process that occurs in different locations in the cytosol and mitochondria and metabolises organic compounds, aerobically or anaerobically, to release useable energy in the form of ATP; the overall process can be represented as a balanced chemical equation (ACSBL053)

Multicellular organisms

Multicellular organisms have a hierarchical structural organisation of cells, tissues, organs and systems (ACSBL054)

The specialised structure and function of tissues, organs and systems can be related to cell differentiation and cell specialisation (ACSBL055)

In animals, the exchange of gases between the internal and external environments of the organism is facilitated by the structure and function of the respiratory system at cell and tissue levels (ACSBL056)

In animals, the exchange of nutrients and wastes between the internal and external environments of the organism is facilitated by the structure and function of the cells and tissues of the digestive system (for example, villi structure and function), and the excretory system (for example, nephron structure and function) (ACSBL057)

In animals, the transport of materials within the internal environment for exchange with cells is facilitated by the structure and function of the circulatory system at cell and tissue levels (for example, the structure and function of capillaries) (ACSBL058)

In plants, gases are exchanged via stomata and the plant surface; their movement within the plant by diffusion does not involve the plant transport system (ACSBL059)

In plants, transport of water and mineral nutrients from the roots occurs via xylem involving root pressure, transpiration and cohesion of water molecules; transport of the products of photosynthesis and some mineral nutrients occurs by translocation in the phloem (ACSBL060)

Units 1 and 2 Achievement Standards

Biology concepts, models and applications

A	B	C	D	E
For the biological systems studied, the student:	*For the biological systems studied, the student:*	*For the biological systems studied, the*	*For the biological systems studied, the*	*For the biological systems studied,*

Biology concepts, models and applications

• analyses how system components function and are interrelated at micro and macro levels • analyses how flows of matter and transfers and transformations of energy are related in system processes • explains the theories and model/s used to explain the system and the aspects of the system they include • applies theories and models of systems and processes to explain phenomena, interpret complex problems and make reasoned, plausible predictions in unfamiliar contexts *For the biological contexts studied, the student:* • analyses the role of collaboration, debate and review, and technologies, in the development of biological theories and models • evaluates how biological science has been used in concert with other sciences to meet diverse needs and inform decision making; and how these applications are influenced by interacting social, economic and ethical factors	• explains how system components are interrelated and how they function • explains the role of system components in processes involving flows of matter and transfers and transformations of energy • describes the theories and model/s used to explain the system • applies theories and models of systems and processes to explain phenomena, interpret problems and make plausible predictions in unfamiliar contexts *For the biological contexts studied, the student*: • explains the role of collaboration, debate and review, and technologies, in the development of biological theories and models • explains how biological science has been used to meet diverse needs and inform decision making; and how these applications are influenced by social, economic and ethical factors	*student:* • describes the system components and their function • describes the ways in which matter and energy move through the system • describes a theory or model used to explain the system • applies theories or models of systems and processes to explain phenomena, interpret problems and make plausible predictions in familiar contexts *For the biological contexts studied, the student:* • describes the role of collaboration and review, and technologies, in the development of biological theories or models • discusses how biological science has been used to meet needs and inform decision making, and some social, economic or ethical implications of these applications	*student:* • identifies the system components • describes observable processes and phenomena • identifies aspects of a theory or model related to the system • describes phenomena, interprets simple problems and makes simple predictions in familiar contexts *For the biological contexts studied, the student:* • describes the role of communication and new evidence in developing biological knowledge • describes ways in which biological science has been used in society to meet needs and identifies some implications of these applications	*the student:* • identifies some parts of the system • describes some observable phenomena • identifies aspects of a theory or model related to parts of the system • describes phenomena and makes simple predictions in familiar, simple contexts *For the biological contexts studied, the student:* • identifies that biological knowledge has changed over time • identifies ways in which biological science has been used in society to meet needs

Biology inquiry skills

A	B	C	D	E
For the biological contexts studied, the student:	*For the biological contexts studied, the student:*	*For the biological contexts studied, the*	*For the biological contexts studied, the*	*For the biological contexts studied, the*

Biology inquiry skills

		student:	student:	student:

Biology inquiry skills

• designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories and develops evidence-based conclusions that identify limitations • evaluates processes and claims, and provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and to solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories 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 describe complex relationships and to solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies and sources of error • selects data to demonstrate relationships linked to biological knowledge and provides conclusions based on data • evaluates processes and claims, and suggests improvements or alternatives • selects, constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

Unit 3: Heredity and continuity of life

Unit Description

Heredity is an important biological principle as it explains why offspring (cells or organisms) resemble their parent cell or organism. Organisms require cellular division and differentiation for growth, development, repair and sexual reproduction. In this unit, students investigate the biochemical and cellular systems and processes involved in the transmission of genetic material to the next generation of cells and to offspring. They consider different patterns of inheritance by analysing the possible genotypes and phenotypes of offspring. Students link their observations to explanatory models that describe patterns of inheritance, and explore how the use of predictive models of inheritance enables decision making.

Students investigate the genetic basis for the theory of evolution by natural selection through constructing, using and evaluating explanatory and predictive models for gene pool diversity of populations. They explore genetic variation in gene pools, selection pressures and isolation effects in order to explain speciation and extinction events and to make predictions about future changes to populations.

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

Students use science inquiry skills to design and conduct investigations into how different factors affect cellular processes and gene pools; they construct and use models to analyse the data gathered; and they continue to develop their skills in constructing plausible predictions and valid, reliable conclusions.

Learning Outcomes

By the end of this unit, students:

- understand the cellular processes and mechanisms that ensure the continuity of life, and how these processes contribute to unity and diversity within a species
- understand the processes and mechanisms that explain how life on Earth has persisted, changed and diversified over the last 3.5 billion years
- understand how models and theories have developed over time; and the ways in which biological knowledge interacts with social, economic, cultural and ethical considerations in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into heredity, gene technology applications, and population gene pool changes
- evaluate with reference to empirical evidence, claims about heredity processes, gene technology, and population gene pool processes, and justify evaluations
- communicate biological understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Biology Unit 3)

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSBL061)

Design investigations, including the procedure/s 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, including animal ethics (ACSBL062)

Conduct investigations, including the use of probabilities to predict inheritance patterns, real or virtual gel electrophoresis, and population simulations to predict population changes, safely, competently and methodically for the collection of valid and reliable data (ACSBL063)

Represent data in meaningful and useful ways, including the use of mean, median, range and probability; organise and analyse data to identify trends, patterns and relationships; discuss the ways in which measurement error, instrumental accuracy, the nature of the procedure and the sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSBL064)

Interpret a range of scientific and media texts, and evaluate models, processes, claims and conclusions by considering the quality of available evidence, including interpreting confidence intervals in secondary data; and use reasoning to construct scientific arguments (ACSBL065)

Select, construct and use appropriate representations, including models of DNA replication, transcription and translation, Punnett squares and probability models of expression of a specific gene in a population, to communicate conceptual understanding, solve problems and make predictions (ACSBL066)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSBL067)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL068)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSBL069)

The acceptance of scientific knowledge can be influenced by the social, economic and cultural context in which it is considered (ACSBL070)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSBL071)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSBL072)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL073)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL074)

Science Understanding

DNA, genes and the continuity of life

Continuity of life requires the replication of genetic material and its transfer to the next generation through processes including binary fission, mitosis, meiosis and fertilisation (ACSBL075)

DNA is a helical double-stranded molecule that occurs bound to proteins in chromosomes in the nucleus, and as unbound circular DNA in the cytosol of prokaryotes and in the mitochondria and chloroplasts of eukaryotic cells (ACSBL076)

The structural properties of the DNA molecule, including nucleotide composition and pairing and the weak bonds between strands of DNA, allow for replication (ACSBL077)

Genes include ‘coding’ and ‘non-coding’ DNA, and many genes contain information for protein production (ACSBL078)

Protein synthesis involves transcription of a gene into messenger RNA in the nucleus, and translation into an amino acid sequence at the ribosome (ACSBL079)

Proteins, including enzymes, are essential to cell structure and functioning (ACSBL080)

The phenotypic expression of genes depends on factors controlling transcription and translation during protein synthesis, the products of other genes, and the environment (ACSBL081)

Mutations in genes and chromosomes can result from errors in DNA replication or cell division, or from damage by physical or chemical factors in the environment (ACSBL082)

Differential gene expression controls cell differentiation for tissue formation, as well as the structural changes that occur during growth (ACSBL083)

Variations in the genotype of offspring arise as a result of the processes of meiosis and fertilisation, as well as a result of mutations (ACSBL084)

Frequencies of genotypes and phenotypes of offspring can be predicted using probability models, including Punnett squares, and by taking into consideration patterns of inheritance, including the effects of dominant, autosomal and sex-linked alleles and multiple alleles, and polygenic inheritance (ACSBL085)

DNA sequencing enables mapping of species genomes; DNA profiling identifies the unique genetic makeup of individuals (ACSBL086)

Biotechnology can involve the use of bacterial enzymes, plasmids as vectors, and techniques including gel electrophoresis, bacterial transformations and PCR (ACSBL087)

Continuity of life on Earth

Life has existed on Earth for approximately 3.5 billion years and has changed and diversified over time (ACSBL088)

Comparative genomics provides evidence for the theory of evolution (ACSBL089)

Natural selection occurs when selection pressures in the environment confer a selective advantage on a specific phenotype to enhance its survival and reproduction; this results in changes in allele frequency in the gene pool of a population (ACSBL090)

In additional to environmental selection pressures, mutation, gene flow and genetic drift can contribute to changes in allele frequency in a population gene pool and results in micro-evolutionary change (ACSBL091)

Mutation is the ultimate source of genetic variation as it introduces new alleles into a population (ACSBL092)

Speciation and macro-evolutionary changes result from an accumulation of micro-evolutionary changes over time (ACSBL093)

Differing selection pressures between geographically isolated populations may lead to allopatric speciation (ACSBL094)

Populations with reduced genetic diversity face increased risk of extinction (ACSBL095)

Biology

Unit 4: Maintaining the internal environment

Unit Description

In order to survive, organisms must be able to maintain system structure and function in the face of changes in their external and internal environments. Changes in temperature and water availability, and the incidence and spread of infectious disease, present significant challenges for organisms and require coordinated system responses. In this unit, students investigate how homeostatic response systems control organisms' responses to environmental change – internal and external – in order to survive in a variety of environments, as long as the conditions are within their tolerance limits. Students study how the invasion of an organism's internal environment by pathogens challenges the effective functioning of cells, tissues and body systems, and triggers a series of responses or events in the short- and long-term in order to maintain system function. They consider the factors that contribute to the spread of infectious disease and how outbreaks of infectious disease can be predicted, monitored and contained.

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

Students use science inquiry skills to investigate a range of responses by plants and animals to changes in their environments and to invasion by pathogens; they construct and use appropriate representations to analyse the data gathered; and they continue to develop their skills in constructing plausible predictions and valid conclusions.

Learning Outcomes

By the end of this unit, students:

- understand the mechanisms by which plants and animals use homeostasis to control their internal environment in a changing external environment
- understand how plants and animals respond to the presence of pathogens, and the ways in which infection, transmission and spread of disease occur
- understand how models and theories have developed over time, and the ways in which biological knowledge interacts with social, economic, cultural and ethical considerations in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into organisms' responses to changing environmental conditions and infectious disease
- evaluate, with reference to empirical evidence, claims about organisms' responses to changing environmental conditions and infectious disease and justify evaluations
- communicate biological understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Biology Unit 4)

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSBL096)

Design investigations, including the procedure/s 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, including the rights of living organisms (ACSBL097)

Conduct investigations, including using models of homeostasis and disease transmission, safely, competently and methodically for valid and reliable collection of data (ACSBL098)

Represent data in meaningful and useful ways, including the use of mean, median, range and probability; organise and analyse data to identify trends, patterns and relationships; discuss the ways in which measurement error, instrumental accuracy, the nature of the procedure and sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSBL099)

Interpret a range of scientific and media texts, and evaluate models, processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSBL100)

Select, construct and use appropriate representations, including diagrams and flow charts, to communicate conceptual understanding, solve problems and make predictions (ACSBL101)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSBL102)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSBL103)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSBL104)

The acceptance of scientific knowledge can be influenced by the social, economic and cultural context in which it is considered (ACSBL105)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSBL106)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSBL107)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSBL108)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSBL109)

Science Understanding

Homeostasis

Homeostasis involves a stimulus-response model in which change in external or internal environmental conditions is detected and appropriate responses occur via negative feedback; in vertebrates, receptors and effectors are linked via a control centre by nervous and/or hormonal pathways (ACSBL110)

Changes in an organism's metabolic activity, in addition to structural features and changes in physiological processes and behaviour, enable the organism to maintain its internal environment within tolerance limits (ACSBL111)

Neural pathways consist of cells that transport nerve impulses from sensory receptors to neurons and on to effectors; the passage of nerve impulses involves transmission of an action potential along a nerve axon and synaptic transmission by neurotransmitters and signal transduction (ACSBL112)

Hormones alter the metabolism of target cells, tissues or organs by increasing or decreasing their activity; in animals, most hormones are produced in endocrine glands as a result of nervous or chemical stimulation, and travel via the circulatory or lymph system to the target cells, tissues or organs (ACSBL113)

Endothermic animals have varying thermoregulatory mechanisms that involve structural features, behavioural responses and physiological and homeostatic mechanisms to control heat exchange and metabolic activity (ACSBL114)

Animals, whether osmoregulators or osmoconformers, and plants, have various mechanisms to maintain water balance that involve structural features, and behavioural, physiological and homeostatic responses (ACSBL115)

Infectious disease

Infectious disease differs from other disease (for example, genetic and lifestyle diseases) in that it is caused by invasion by a pathogen and can be transmitted from one host to another (ACSBL116)

Pathogens include prions, viruses, bacteria, fungi, protists and parasites (ACSBL117)

Pathogens have adaptations that facilitate their entry into cells and tissues and their transmission between hosts; transmission occurs by various mechanisms including through direct contact, contact with body fluids, and via contaminated food, water or disease-specific vectors (ACSBL118)

When a pathogen enters a host, it causes physical or chemical changes (for example, the introduction of foreign chemicals via the surface of the pathogen, or the production of toxins) in the cells or tissues; these changes stimulate the host immune responses (ACSBL119)

All plants and animals have innate (general) immune responses to the presence of pathogens; vertebrates also have adaptive immune responses (ACSBL120)

Innate responses in animals target pathogens, including through the inflammation response, which involves the actions of phagocytes, defensins and the complement system (ACSBL121)

In vertebrates, adaptive responses to specific antigens include the production of humoral immunity through the production of antibodies by B lymphocytes, and the provision of cell-mediated immunity by T lymphocytes; in both cases memory cells are produced that confirm long-term immunity to the specific antigen (ACSBL122)

In vertebrates, immunity may be passive (for example, antibodies gained via the placenta or via antibody serum injection) or active (for example, acquired through actions of the immune system as a result of natural exposure to a pathogen or through the use of vaccines) (ACSBL123)

Transmission and spread of disease is facilitated by regional and global movement of organisms (ACSBL124)

The spread of a specific disease involves a wide range of interrelated factors (for example, persistence of the pathogen within hosts, the transmission mechanism, the proportion of the population that are immune or have been immunised, and the mobility of individuals of the affected population); analysis of these factors can enable prediction of the potential for an outbreak, as well as evaluation of strategies to control the spread of disease (ACSBL125)

Units 3 and 4 Achievement Standards

Biology concepts, models and applications

A	B	C	D	E
For the biological systems studied, the student	*For the biological systems studied, the student*	*For the biological systems studied, the*	*For the biological systems studied, the*	*For the biological systems studied,*

Biology concepts, models and applications

		student	*student*	*the student*

Biology concepts, models and applications

• analyses how system components function and are interrelated across a range of scales to enable continuity of individuals, populations and species • analyses how the function and interrelationships of system components are affected by external factors across a range of scales, and how the system responds over time • explains the theories and model/s used to explain the system, the supporting evidence, and their limitations and assumption • applies theories and models of systems and processes to explain phenomena, critically analyse complex problems, and make reasoned, plausible predictions in unfamiliar contexts *For the biological contexts studied, the student:*	• explains how system components are interrelated and how they function to enable continuity of individuals, populations and species • explains how the function and interrelationships of system components are affected by external factors, and how the system responds • describes the theories and model/s used to explain the system, some supporting evidence, and their limitations • applies theories and models of systems and processes to explain phenomena, analyse problems, and make plausible predictions in	• describes how system components function and the processes that enable continuity of the individual, population and species • describes how system components or processes are affected by external factors, and how the system responds • describes key aspects of a theory or model used to explain system processes, and the phenomena to which they can be applied • applies theories or models of systems and processes to explain phenomena, interpret problems, and	• identifies system components that contribute to the survival of an organism, population or species • describes changes to the system, the external factors that caused those changes, and some system responses • describes key aspects of a theory or model used to explain a system process • describes phenomena, interprets simple problems, and makes predictions in familiar contexts *For the biological contexts studied, the student:*	• identifies some parts of the system that contribute to the survival of an organism, population or species • describes a change to the system, and an external factor that caused that change • identifies aspects of a theory or model related to a system process • describes phenomena and makes simple predictions in familiar contexts *For the biological contexts studied, the student:*

Biology concepts, models and applications

• analyses the roles of collaboration, debate and review, and technologies, in the development of biological theories and models • evaluates how biological science has been used in concert with other sciences to meet diverse needs and to inform decision making; and how these applications are influenced by interacting social, economic and ethical factors	unfamiliar contexts *For the biological contexts studied, the student:* • explains the role of collaboration, debate and review, and technologies, in the development of biological theories and models • explains how biological science has been used to meet diverse needs and to inform decision making; and how these applications are influenced by social, economic and ethical factors	make plausible predictions in some unfamiliar contexts *For the biological contexts studied, the student:* • describes the role of collaboration and review, and technologies, in the development of biological theories or models • discusses how biological science has been used to meet needs and to inform decision making, and some social, economic or ethical implications of these applications	*student:* • describes the roles of communication and new evidence in developing biological knowledge • describes ways in which biological science has been used in society to meet needs, and identifies some implications of these applications	• identifies that biological knowledge has changed over time • identifies ways in which biological science has been used in society to meet needs

Biology inquiry skills

A	B	C	D	E
For the biological contexts studied, the student:	*For the biological contexts studied, the student:*	*For the biological contexts studied, the*	*For the biological contexts studied, the*	*For the biological contexts studied, the*

Biology inquiry skills

		student:	*student:*	*student:*
• designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data, and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories, and develops evidence-based conclusions that identify limitations • evaluates processes and claims, and provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and to solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies, and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories, 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 describe complex relationships and to solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies, and sources of error • selects data to demonstrate relationships linked to biological knowledge, and provides conclusions based on data • evaluates processes and claims, and suggests improvements or alternatives • selects, constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends, and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

Biology Glossary

Accuracy
The extent to which a measurement result represents the quantity it purports to measure; an accurate measurement result includes an estimate of the true value and an estimate of the uncertainty.

Animal ethics
Animal ethics involves consideration of respectful, fair and just treatment of animals. The use of animals in science involves consideration of replacement (substitution of insentient materials for conscious living animals), reduction (using only the minimum number of animals to satisfy research statistical requirements) and refinement (decrease in the incidence or severity of 'inhumane' procedures applied to those animals that still have to be used).

Biogeochemical cycles
Pathways by which chemical substances move through the biosphere, lithosphere, atmosphere, and hydrosphere.

Biosecurity
Policy and regulatory frameworks designed to safeguard against biological threats to environments, organisms and human health; biosecurity measures aim to restrict entry of disease causing agents, genetically modified species, or invasive alien species or genotypes.

Biotechnology
The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for human purposes.

Comparative genomics
The study and comparison of the genome sequences of different species; comparative genomics enables identification of genes that are conserved or common among species, as well as genes that give each organism its unique characteristics.

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.

Ecological survey techniques
Techniques used to survey, measure, quantify, assess and monitor biodiversity and ecosystems in the field; techniques used depend on the subject and purpose of the study. Techniques may include random quadrats, transects, capture - recapture, nest survey, netting, trapping, flight interception, beating trays, dry extraction from leaf litter samples, 3-minute habitat-proportional sampling of aquatic habitats, aerial surveys and soil, air and water sampling.

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.

Field work
Observational research undertaken in the normal environment of the subject of the study.

Genre
The categories into which texts are grouped; genre distinguishes texts on the basis of their subject matter, form and structure (for example, scientific reports, field guides, explanations, procedures, biographies, media articles, persuasive texts, narratives).

Hypothesis
A tentative explanation for an observed phenomenon, expressed as a precise and unambiguous statement 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. Investigations can include observation, research, field work, laboratory experimentation and manipulation of simulations.

Law
A statement describing invariable relationships between phenomena in specified conditions, frequently expressed mathematically.

Measurement error
The difference between the measurement result and a currently accepted or standard value of a quantity.

Media texts
Spoken, print, graphic or electronic communications with a public audience. Media texts can be found in newspapers, magazines and on television, film, radio, computer software and the internet.

Mode
The various processes of communication – listening, speaking, reading/viewing and writing/creating.

Model
A representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea.

Population
A group of organisms of one species that interbreed and live in the same place at the same time.

Primary data
Data collected directly by a person or group.

Primary source
Report of data created by the person or persons directly involved in observations of one or more events, experiments, investigations or projects.

Reliability
The degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

Reliable data
Data that has been judged to have a high level of reliability; reliability is the degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

Representation

A verbal, visual, physical or mathematical demonstration of understanding of a science concept or concepts. A concept can be represented in a range of ways and using multiple modes.

Research

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

Research ethics

Norms of conduct that determine ethical research behaviour; research ethics are governed by principles such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics.

Risk assessment

Evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities. Requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate.

Secondary data

Data collected by a person or group other than the person or group using the data.

Secondary source

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

Simulation

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

System

A group of interacting objects, materials or processes that form an integrated whole. Systems can be open or closed.

Theory

A set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena. Theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power.

Uncertainty

Range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment.

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.

The Australian Curriculum
Chemistry

AUSTRALIAN CURRICULUM, ASSESSMENT AND REPORTING AUTHORITY

Chemistry

Rationale and Aims

Rationale

Chemistry is the study of materials and substances, and the transformations they undergo through interactions and the transfer of energy. Chemists can use an understanding of chemical structures and processes to adapt, control and manipulate systems to meet particular economic, environmental and social needs. This includes addressing the global challenges of climate change and security of water, food and energy supplies, and designing processes to maximise the efficient use of Earth’s finite resources. Chemistry develops students' understanding of the key chemical concepts and models of structure, bonding, and chemical change, including the role of chemical, electrical and thermal energy. Students learn how models of structure and bonding enable chemists to predict properties and reactions and to adapt these for particular purposes.

Students explore key concepts and models through active inquiry into phenomena and through contexts that exemplify the role of chemistry and chemists in society. Students design and conduct qualitative and quantitative investigations both individually and collaboratively. They investigate questions and hypotheses, manipulate variables, analyse data, evaluate claims, solve problems and develop and communicate evidence-based arguments and models. Thinking in chemistry involves using differing scales including macro-, micro- and nano-scales; using specialised representations such as chemical symbols and equations; and being creative, as when designing new materials or models of chemical systems. The study of chemistry provides a foundation for undertaking investigations in a wide range of scientific fields and often provides the unifying link across interdisciplinary studies.

Some of the major challenges and opportunities facing Australia and the Asia-Pacific region at the beginning of the twenty-first century are inextricably associated with chemistry. Issues of sustainability on local, national and global levels are, and will continue to be, tackled by the application of chemical knowledge, using a range of technologies. These include issues such as the supply of clean drinking water, efficient production and use of energy, management of mineral resources, increasing acidification of the oceans, and climate change.

Studying senior secondary Science provides students with a suite of skills and understandings that are valuable to a wide range of further study pathways and careers. An understanding of chemistry is relevant to a range of careers, including those in forensic science, environmental science, engineering, medicine, pharmacy and sports science. Additionally, chemistry knowledge is valuable in occupations that rely on an understanding of materials and their interactions, such as art, winemaking, agriculture and food technology. Some students will use this course as a foundation to pursue further studies in chemistry, and all students will become more informed citizens, able to use chemical knowledge to inform evidence-based decision making and engage critically with contemporary scientific issues.

Aims

Chemistry aims to develop students’:

- interest in and appreciation of chemistry and its usefulness in helping to explain phenomena and solve problems encountered in their ever-changing world
- understanding of the theories and models used to describe, explain and make predictions about chemical systems, structures and properties
- understanding of the factors that affect chemical systems, and how chemical systems can be controlled to produce desired products
- appreciation of chemistry as an experimental science that has developed through independent and collaborative research, and that has significant impacts on society and implications for decision making

- expertise in conducting a range of scientific investigations, including the collection and analysis of qualitative and quantitative data and the interpretation of evidence
- ability to critically evaluate and debate scientific arguments and claims in order to solve problems and generate informed, responsible and ethical conclusions
- ability to communicate chemical understanding and findings to a range of audiences, including through the use of appropriate representations, language and nomenclature.

Organisation

Overview of senior secondary Australian Curriculum

ACARA has developed senior secondary Australian Curriculum for English, Mathematics, Science and History according to a set of design specifications. The ACARA Board approved these specifications following consultation with state and territory curriculum, assessment and certification authorities.

The senior secondary Australian Curriculum specifies 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) expected of 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 and examinations). 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 their courses. They 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 local courses that integrate the Australian Curriculum content and achievement standards and any additional information, guidelines and rules to satisfy local requirements including advice on entry and exit points and credit for completed study.

The senior secondary Australian Curriculum for each subject should not, therefore, be read as a course of study. Rather, it is presented as content and achievement standards for integration into state and territory courses.

Senior secondary Science subjects

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

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

Structure of Chemistry

Units

In Chemistry, students develop their understanding of chemical systems, and how models of matter and energy transfers and transformations can be used to describe, explain and predict chemical structures, properties and reactions. There are four units:

- Unit 1: Chemical fundamentals: structure, properties and reactions
- Unit 2: Molecular interactions and reactions
- Unit 3: Equilibrium, acids and redox reactions
- Unit 4: Structure, synthesis and design.

In Unit 1, students use models of atomic structure and bonding to explain the macroscopic properties of materials and to predict the products and explain the energy changes associated with chemical reactions. In Unit 2, they continue to develop their understanding of bonding models and the relationship between structure, properties and reactions, including consideration of the factors that affect the rate of chemical reactions.

In Units 3 and 4, students further develop their knowledge of chemical processes introduced in Units 1 and 2, including considering energy transfers and transformations, calculations of chemical quantities, rates of reaction and chemical systems. In Unit 3, students investigate models of equilibrium in chemical systems; apply these models in the context of acids and bases and redox reactions, including electrochemical cells; and explain and predict how a range of factors affect these systems. In Unit 4, students use models of molecular structure, chemical reactions and energy changes to explain and apply synthesis processes, particularly with consideration of organic synthesis; and they consider current and future applications of chemical design principles.

Each unit includes:

- Unit descriptions – short descriptions of the purpose of and rationale for each unit
- Learning outcomes – six to eight statements describing the learning expected as a result of studying the unit
- Content descriptions – descriptions of the core content to be taught and learned,organised into three strands:
  - *Science Inquiry Skills*
  - *Science as a Human Endeavour*
  - *Science Understanding (organised in sub-units).*

Organisation of content

The Australian Curriculum: Science has three interrelated strands: *Science Inquiry Skills, Science as a Human Endeavour* and *Science Understanding*. These strands are used to organise the Science learning area from Foundation to Year 12. In the Senior Secondary Science subjects, the three strands build on students' learning in the F-10 Australian Curriculum: Science.

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. Students' experiences of school science should mirror 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 for *Science Inquiry Skills*, *Science as a Human Endeavour* and *Science Understanding* have been written so that this integration is possible in each unit.

Science Inquiry Skills

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

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

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

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 more specific skills to be taught within the 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:

- Identifying, researching and constructing questions for investigation; proposing hypotheses; and predicting possible outcomes
- Designing investigations, including the procedure/s 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
- Conducting investigations, including using equipment and techniques safely, competently and methodically for the collection of valid and reliable data
- Representing data in meaningful and useful ways; organising and analysing data to identify trends, patterns and relationships; recognising error, uncertainty and limitations in data; and selecting, synthesising and using evidence to construct and justify conclusions
- Interpreting scientific and media texts and evaluating processes, claims and conclusions by considering the quality of available evidence; and using reasoning to construct scientific arguments
- Selecting, constructing and using appropriate representations to communicate understanding, solve problems and make predictions
- Communicating to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes.

The senior secondary Science subjects have been designed to accommodate, if appropriate, an extended scientific investigation within 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.

Science as a Human Endeavour

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

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

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

Across the senior secondary Science subjects, the same set of *Science as a Human Endeavour* content descriptions is used for Units 1 and 2 of the subjects; and another set for Units 3 and 4. This consistent approach enables students to develop a rich appreciation of the complex ways in which science interacts with society, through the exploration of *Science as a Human Endeavour* concepts across the subjects and in multiple contexts.

'Examples in context' will be developed to illustrate possible contexts related to *Science Understanding* content, in which students could explore *Science as a Human Endeavour* concepts. These will be made available to complement the final online curriculum. Each *Example in context* will be aligned to the relevant sub-unit in *Science Understanding* and will include links to the relevant *Science as a Human Endeavour* content descriptions.

Science Understanding

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

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

Science Understanding can be developed through the selection of contexts that have relevance to and are engaging for students. The Australian Curriculum: Science has been designed to provide jurisdictions, schools and teachers with the flexibility to select contexts that meet the social, geographic and learning needs of their students.

Organisation of achievement standards

The Chemistry achievement standards are organised by two dimensions: 'Chemistry Concepts, Models and Applications', and 'Chemistry Inquiry Skills'. They describe five levels of student achievement.

'Chemistry 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. 'Chemistry Inquiry Skills' describes the skills students demonstrate when investigating the content developed through the strands of *Science Understanding* and *Science as a Human Endeavour*.

Senior secondary achievement standards have been written for each Australian Curriculum senior secondary subject. The achievement standards provide an indication of typical performance at five different levels (corresponding to grades A to E) following the completion of study of senior secondary Australian Curriculum content for a pair of units. They are broad statements of understanding and skills that are best read and understood in conjunction with the relevant unit content. They are structured to reflect key dimensions of the content of the relevant learning area. They will be eventually accompanied by illustrative and annotated samples of student work/ performance/ responses.

The achievement standards will be refined empirically through an analysis of samples of student work and responses to assessment tasks: they cannot be maintained *a priori* without reference to actual student performance. Inferences can be drawn about the quality of student learning on the basis of observable differences in the extent, complexity, sophistication and generality of the understanding and skills typically demonstrated by students in response to well-designed assessment activities and tasks.

In the short term, achievement standards will inform assessment processes used by curriculum, assessment and certifying authorities for course offerings based on senior secondary Australian Curriculum content.

ACARA has made reference to a common syntax (as a guide, not a rule) in constructing the achievement standards across the learning areas. The common syntax that has guided development is as follows:

- Given a specified context (as described in the curriculum content)
- With a defined level of consistency/accuracy (the assumption that each level describes what the student does well, competently, independently, consistently)
- Students perform a specified action (described through a verb)
- In relation to what is valued in the curriculum (specified as the object or subject)
- With a defined degree of sophistication, difficulty, complexity (described as an indication of quality)

Terms such as 'analyse' and 'describe' have been used to specify particular action but these can have everyday meanings that are quite general. ACARA has therefore associated these terms with specific meanings that are defined in the senior secondary achievement standards glossary and used precisely and consistently across subject areas.

Links to Foundation to Year 10

Progression from the F-10 Australian Curriculum: Science

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

In particular, the Chemistry curriculum continues to develop the key concepts introduced in the Chemical Sciences sub-strand, that is, that the chemical and physical properties of substances are determined by their structure at an atomic scale; and that substances change and new substances are produced by the rearrangement of atoms through atomic interactions and energy transfer.

Mathematical skills expected of students studying Chemistry

The Chemistry 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 arguments, claims or conclusions. In gathering and recording numerical data, students are required to make measurements with an appropriate degree of accuracy and to represent measurements using appropriate units.

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

Students may need to be taught to interpret logarithmic scales and to use a calculator to substitute a value to evaluate a logarithmic expression as they are required in pH calculations (Unit 3), but are not part of the Year 10 Australian Curriculum: Mathematics.

It is assumed that students will be able to competently:

- perform calculations involving addition, subtraction, multiplication and division of quantities
- perform approximate evaluations of numerical expressions
- express fractions as percentages, and percentages as fractions
- calculate percentages

- recognise and use ratios
- transform decimal notation to power of ten notation
- change the subject of a simple equation
- substitute physical quantities into an equation using consistent units so as to calculate one quantity and check the dimensional consistency of such calculations
- solve simple algebraic equations
- comprehend and use the symbols/notations $<$, $>$, Δ, $\approx$
- translate information between graphical, numerical and algebraic forms
- distinguish between discrete and continuous data and then select appropriate forms, variables and scales for constructing graphs
- construct and interpret frequency tables and diagrams, pie charts and histograms
- describe and compare data sets using mean, median and inter-quartile range
- interpret the slope of a linear graph.

Representation of General capabilities

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

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

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

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

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

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

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

Representation of Cross-curriculum priorities

While the significance of the cross-curriculum priorities for Chemistry varies, there are opportunities for teachers to select contexts that incorporate the key concepts from each priority.

Through an investigation of contexts that draw on *Aboriginal and Torres Strait Islander histories and cultures* students can appreciate the role of Aboriginal and Torres Strait Islander Peoples' knowledge in developing richer understandings of the chemical diversity in the Australian environment, for example the chemical properties of plants used for bush medicines, or mineral ores used for decoration or artwork.

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

In Chemistry, the *Sustainability* cross-curriculum priority provides authentic contexts for exploring, investigating and understanding the function and interactions of chemical systems. Chemistry explores a wide range of chemical systems that operate at different time and spatial scales. By investigating the relationships between chemical systems and system components, and how systems respond to change, students develop an appreciation for the ways in which interactions between matter and energy connect Earth's biosphere, geosphere, hydrosphere and atmosphere. Students appreciate that chemical science and its applications provide 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, such as ocean acidification, mineral extraction or use of fossil fuels, and to develop management plans, alternative technologies or approaches such as green chemistry that minimise these effects and provide for a more sustainable future.

Safety

Science learning experiences may involve the use of potentially hazardous substances and/or hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students and that school practices meet the requirements of the *Work Health and Safety Act 2011,* in addition to relevant state 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.

Animal ethics

Through a consideration of research ethics as part of *Science Inquiry Skills*, students will examine their own ethical position, draw on ethical perspectives when designing investigation methods, and ensure that any activities that impact on living organisms comply with the *Australian code of practice for the care and use of animals for scientific purposes 7th edition* (2004) (http://www.nhmrc.gov.au/guidelines/publications/ea16) .

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*, in addition to relevant state or territory guidelines.

When state and territory curriculum authorities integrate the Australian Curriculum into local courses, they will include more specific advice on the care and use of, or interaction with, animals.

For further information about relevant guidelines or to access your local Animal Ethics Committee, contact your state or territory curriculum authority.

Unit 1: Chemical fundamentals: structure, properties and reactions

Unit Description

Chemists design and produce a vast range of materials for many purposes, including for fuels, cosmetics, building materials and pharmaceuticals. As the science of chemistry has developed over time, there has been an increasing realisation that the properties of a material depend on, and can be explained by, the material's structure. A range of models at the atomic and molecular scale enable explanation and prediction of the structure of materials and how this structure influences properties and reactions. In this unit, students relate matter and energy in chemical reactions, as they consider the breaking and reforming of bonds as new substances are produced. Students can use materials that they encounter in their lives as a context for investigating the relationships between structure and properties.

Through the investigation of appropriate contexts, students explore how evidence from multiple disciplines and individuals and the development of ICT and other technologies have contributed to developing understanding of atomic structure and chemical bonding. They explore how scientific knowledge is used to offer reliable explanations and predictions, and the ways in which it interacts with social, economic, cultural and ethical factors.

Students use science inquiry skills to develop their understanding of patterns in the properties and composition of materials. They investigate the structure of materials by describing physical and chemical properties at the macroscopic scale, and use models of structure and primary bonding at the atomic and sub-atomic scale to explain these properties. They are introduced to the mole concept as a means of quantifying matter in chemical reactions.

Learning Outcomes

By the end of this unit, students:

- understand how the atomic model and models of bonding explain the structure and properties of elements and compounds
- understand the concept of enthalpy, and apply this to qualitatively and quantitatively describe and explain energy changes in chemical reactions
- understand how models and theories have developed based on evidence from a range of sources, and the uses and limitations of chemical knowledge in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into the properties of elements, compounds and mixtures and the energy changes involved in chemical reactions
- evaluate, with reference to empirical evidence, claims about chemical properties, structures and reactions
- communicate, predict and explain chemical phenomena using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Chemistry Unit 1)

Identify, research and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSCH001)

Design investigations, including the procedure/s 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 (ACSCH002)

Conduct investigations, including the use of devices to accurately measure temperature change and mass, safely, competently and methodically for the collection of valid and reliable data (ACSCH003)

Represent data in meaningful and useful ways, including using appropriate graphic representations and correct units and symbols; organise and process data to identify trends, patterns and relationships; identify sources of random and systematic error and estimate their effect on measurement results; and select, synthesise and use evidence to make and justify conclusions (ACSCH004)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSCH005)

Select, construct and use appropriate representations including chemical symbols and formulae, molecular structural formulae, physical and graphical models of structures, chemical equations and thermochemical equations, to communicate conceptual understanding, solve problems and make predictions (ACSCH006)

Select and use appropriate mathematical representations to solve problems and make predictions, including calculating percentage composition from relative atomic masses and using the mole concept to calculate the mass of reactants and products (ACSCH007)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSCH008)

Science as a Human Endeavour (Units 1 and 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSCH009)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSCH010)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSCH011)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSCH012)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSCH013)

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSCH014)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSCH015)

Science Understanding

Properties and structure of atoms

Trends in the observable properties of elements are evident in periods and groups in the periodic table (ACSCH016)

The structure of the periodic table is based on the electron configuration of atoms, and shows trends, including in atomic radii and valencies (ACSCH017)

Atoms can be modelled as a nucleus surrounded by electrons in distinct energy levels, held together by electrostatic forces of attraction between the nucleus and electrons; atoms can be represented using electron shell diagrams (all electron shells or valence shell only) or electron charge clouds (ACSCH018)

Flame tests and atomic absorption spectroscopy are analytical techniques that can be used to identify elements; these methods rely on electron transfer between atomic energy levels (ACSCH019)

The properties of atoms, including their ability to form chemical bonds, are explained by the arrangement of electrons in the atom and in particular by the stability of the valence electron shell (ACSCH020)

Isotopes are atoms of an element with the same number of protons but different numbers of neutrons; different isotopes of elements are represented using atomic symbols (for example, ${}^{12}_{6}\mathrm{C}$, ${}^{13}_{6}\mathrm{C}$) (ACSCH021)

Isotopes of an element have the same electron configuration and possess similar chemical properties but have different physical properties, including variations in nuclear stability (ACSCH022)

Mass spectrometry involves the ionisation of substances and generates spectra which can be analysed to determine the isotopic composition of elements (ACSCH023)

The relative atomic mass of an element is the ratio of the weighted average mass per atom of the naturally occurring form of the element to $\frac{1}{12}$ the mass of an atom of carbon-12; relative atomic masses reflect the isotopic composition of the element (ACSCH024)

Properties and structure of materials

Materials are either pure substances with distinct measurable properties (for example, melting and boiling point, reactivity, strength, density) or mixtures with properties dependent on the identity and relative amounts of the substances that make up the mixture (ACSCH025)

Differences in the properties of substances in a mixture, such as particle size, solubility, magnetism, density, electrostatic attraction, melting point and boiling point, can be used to separate them (ACSCH026)

The type of bonding within substances explains their physical properties, including melting and boiling point, conductivity of both electricity and heat, strength and hardness (ACSCH027)

Nanomaterials are substances that contain particles in the size range 1–100 nm and have specific properties relating to the size of these particles (ACSCH028)

Chemical bonds are caused by electrostatic attractions that arise because of the sharing or transfer of electrons between participating atoms; the valency is a measure of the number of bonds that an atom can form (ACSCH029)

Ions are atoms or groups of atoms that are electrically charged due to an imbalance in the number of electrons and protons; ions are represented by formulae which include the number of constituent atoms and the charge of the ion (for example, O^{2-}, SO_4^{2-}) (ACSCH030)

The properties of ionic compounds (for example, high melting point, brittleness, ability to conduct electricity when liquid or in solution) are explained by modelling ionic bonding as ions arranged in a crystalline lattice structure with forces of attraction between oppositely charged ions (ACSCH031)

The characteristic properties of metals (for example, malleability, thermal conductivity, electrical conductivity) are explained by modelling metallic bonding as a regular arrangement of positive ions (cations) made stable by electrostatic forces of attraction between these ions and the electrons that are free to move within the structure (ACSCH032)

Covalent substances are modelled as molecules or covalent networks that comprise atoms which share electrons, resulting in electrostatic forces of attraction between electrons and the nucleus of more than one atom (ACSCH033)

Elemental carbon exists as a range of allotropes, including graphite, diamond and fullerenes, with significantly different structures and physical properties (ACSCH034)

Carbon forms hydrocarbon compounds, including alkanes and alkenes, with different chemical properties that are influenced by the nature of the bonding within the molecules (ACSCH035)

Chemical reactions: reactants, products and energy change

All chemical reactions involve the creation of new substances and associated energy transformations, commonly observable as changes in the temperature of the surroundings and/or the emission of light (ACSCH036)

Endothermic and exothermic reactions can be explained in terms of the Law of Conservation of Energy and the breaking and reforming of bonds; heat energy released or absorbed can be represented in thermochemical equations (ACSCH037)

Fuels, including fossil fuels and biofuels, can be compared in terms of their energy output, suitability for purpose, and the nature of products of combustion (ACSCH038)

A mole is a precisely defined quantity of matter equal to Avogadro’s number of particles; the mole concept and the Law of Conservation of Mass can be used to calculate the mass of reactants and products in a chemical reaction (ACSCH039)

Chemistry

Unit 2: Molecular interactions and reactions

Unit Description

In this unit, students develop their understanding of the physical and chemical properties of materials including gases, water and aqueous solutions, acids and bases. Students explore the characteristic properties of water that make it essential for physical, chemical and biological processes on Earth, including the properties of aqueous solutions. They investigate and explain the solubility of substances in water, and compare and analyse a range of solutions. They learn how rates of reaction can be measured and altered to meet particular needs, and use models of energy transfer and the structure of matter to explain and predict changes to rates of reaction. Students gain an understanding of how to control the rates of chemical reactions, including through the use of a range of catalysts.

Through the investigation of appropriate contexts, students explore how evidence from multiple disciplines and individuals and the development of ICT and other technologies have contributed to developing understanding of intermolecular forces and chemical reactions. They explore how scientific knowledge is used to offer reliable explanations and predictions, and the ways in which it interacts with social, economic, cultural and ethical factors.

Students use a range of practical and research inquiry skills to investigate chemical reactions, including the prediction and identification of products and the measurement of the rate of reaction. They investigate the behaviour of gases, and use the kinetic theory to predict the effects of changing temperature, volume and pressure in gaseous systems.

Learning Outcomes

By the end of this unit, students:

- understand how models of the shape and structure of molecules and intermolecular forces can be used to explain the properties of substances, including the solubility of substances in water
- understand how kinetic theory can be used to explain the behaviour of gaseous systems, and how collision theory can be used to explain and predict the effect of varying conditions on the rate of reaction
- understand how models and theories have developed based on evidence from multiple disciplines, and the uses and limitations of chemical knowledge in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into the properties and behaviour of gases, water, aqueous solutions and acids and the factors that affect the rate of chemical reactions
- evaluate, with reference to empirical evidence, claims about chemical properties, structures and reactions
- communicate, predict and explain chemical phenomena using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Chemistry Unit 2)

Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSCH040)

Design investigations, including the procedure/s 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 (ACSCH041)

Conduct investigations, including measuring pH and the rate of formation of products, identifying the products of reactions, and testing solubilities, safely, competently and methodically for the collection of valid and reliable data (ACSCH042)

Represent data in meaningful and useful ways, including using appropriate graphic representations and correct units and symbols; organise and process data to identify trends, patterns and relationships; identify sources of random and systematic error; identify anomalous data; estimate the effect of error on measured results; and select, synthesise and use evidence to make and justify conclusions (ACSCH043)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSCH044)

Select, construct and use appropriate representations, including physical and graphical models of molecules, energy profile diagrams, electron dot diagrams, ionic formulae, chemical formulae, chemical equations and phase descriptors for chemical species to communicate conceptual understanding, solve problems and make predictions (ACSCH045)

Select and use appropriate mathematical representations to solve problems and make predictions, including using the mole concept to calculate the mass of chemicals and/or volume of a gas (at standard temperature and pressure) involved in a chemical reaction, and using the relationship between the number of moles of solute, concentration and volume of a solution to calculate unknown values (ACSCH046)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSCH047)

Science as a Human Endeavour (Units 1 and 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review, and reproducibility (ACSCH048)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSCH049)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSCH050)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSCH051)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSCH052)

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSCH053)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSCH054)

Science Understanding

Intermolecular forces and gases

Observable properties, including vapour pressure, melting point, boiling point and solubility, can be explained by considering the nature and strength of intermolecular forces within a substance (ACSCH055)

The shapes of molecules can be explained and predicted using three-dimensional representations of electrons as charge clouds and using valence shell electron pair repulsion (VSEPR) theory (ACSCH056)

The polarity of molecules can be explained and predicted using knowledge of molecular shape, understanding of symmetry, and comparison of the electronegativity of elements (ACSCH057)

The shape and polarity of molecules can be used to explain and predict the nature and strength of intermolecular forces, including dispersion forces, dipole-dipole forces and hydrogen bonding (ACSCH058)

Data from chromatography techniques (for example, thin layer, gas and high-performance liquid chromatography) can be used to determine the composition and purity of substances; the separation of the components is caused by the variation of strength of the interactions between atoms, molecules or ions in the mobile and stationary phases (ACSCH059)

The behaviour of gases, including the qualitative relationships between pressure, temperature and volume, can be explained using kinetic theory (ACSCH060)

Aqueous solutions and acidity

Water is a key substance in a range of chemical systems because of its unique properties, including its boiling point, density in solid and liquid phases, surface tension, and ability to act as a solvent (ACSCH061)

The unique properties of water can be explained by its molecular shape and hydrogen bonding between molecules (ACSCH062)

The concentration of a solution is defined as the amount of solute divided by the amount of solution; this can be represented in a variety of ways including by the number of moles of the solute per litre of solution (mol L^{-1}) and the mass of the solute per litre of solution (g L^{-1}) (ACSCH063)

The presence of specific ions in solutions can be identified using analytical techniques based on chemical reactions, including precipitation and acid-base reactions (ACSCH064)

The solubility of substances in water, including ionic and molecular substances, can be explained by the intermolecular forces between species in the substances and water molecules, and is affected by changes in temperature (ACSCH065)

The pH scale is used to compare the levels of acidity or alkalinity of aqueous solutions; the pH is dependent on the concentration of hydrogen ions in the solution (ACSCH066)

Patterns of the reactions of acids and bases (for example, reactions of acids with bases, metals and carbonates) allow products to be predicted from known reactants (ACSCH067)

Rates of chemical reactions

Varying the conditions present during chemical reactions can affect the rate of the reaction and in some cases the identity of the products (ACSCH068)

The rate of chemical reactions can be quantified by measuring the rate of formation of products or the depletion of reactants (ACSCH069)

Collision theory can be used to explain and predict the effect of concentration, temperature, pressure and surface area on the rate of chemical reactions by considering the structure of the reactants and the energy of particles (ACSCH070)

The activation energy is the minimum energy required for a chemical reaction to occur and is related to the strength of the existing chemical bonds; the magnitude of the activation energy influences the rate of a chemical reaction (ACSCH071)

Energy profile diagrams can be used to represent the enthalpy changes and activation energy associated with a chemical reaction (ACSCH072)

Catalysts, including enzymes and metal nanoparticles, affect the rate of certain reactions by providing an alternative reaction pathway with a reduced activation energy, hence increasing the proportion of collisions that lead to a chemical change (ACSCH073)

Units 1 and 2 Achievement Standards

Chemistry concepts, models and applications

A	B	C	D	E
For the chemical systems studied, the student:	*For the chemical systems studied, the student:*	*For the chemical systems studied, the*	*For the chemical systems studied, the*	*For the chemical systems studied,*

Chemistry concepts, models and applications

- analyses how structure, bond strength and energy transfers and transformations are interrelated in chemical systems - analyses how a range of factors affect atomic or molecular interactions and change the structure and properties of systems - explains the theories and model/s used to explain the system and the aspects of the system they include - applies theories and models of systems and processes to explain phenomena, interpret complex problems, and make reasoned, plausible predictions in unfamiliar contexts *For the chemical science contexts studied, the student:*	- explains how structure, bonding and energy transfers and transformations are interrelated in chemical systems - explains how a range of factors change the structure and properties of chemical systems - describes the theories and model/s used to explain the system - applies theories and models of systems and processes to explain phenomena, interpret problems, and make plausible predictions in unfamiliar contexts *For the chemical science contexts studied, the*	*student:* - describes how structure, bonding and energy transfers are related in chemical systems - describes how some factors change the structure and properties of chemical systems - describes a theory or model used to explain the system - applies theories or models of systems and processes to explain phenomena, interpret problems, and make plausible predictions in familiar contexts	*student:* - describes structure and bonding in substances - describes how some factors affect chemical systems - identifies aspects of a theory or model related to the system - describes phenomena, interprets simple problems, and makes simple predictions in familiar contexts *For the chemical science contexts studied, the student:* - describes the role of communication and now	*the student:* - identifies observable properties of substances - identifies observable changes to chemical systems - identifies aspects of a theory or model related to parts of the system - describes phenomena and makes simple predictions in familiar, simple contexts *For the chemical science contexts studied, the student:*

Chemistry concepts, models and applications

• analyses the roles of collaboration, debate and review, and technologies, in the development of chemical science theories and models • evaluates how chemical science has been used in concert with other sciences to meet diverse needs and inform decision making, and how these applications are influenced by interacting social, economic and ethical factors	*student:* • explains the role of collaboration, debate and review, and technologies, in the development of chemical science theories and models • explains how chemical science has been used to meet diverse needs and inform decision making, and how these applications are influenced by social, economic and ethical factors	*For the chemical science contexts studied, the student:* • describes the role of collaboration and review, and technologies, in the development of chemical science theories or models • discusses how chemical science has been used to meet needs and inform decision making, and some social, economic or ethical implications of these applications	and new evidence in developing chemical science knowledge • describes ways in which chemical science has been used in society to meet needs, and identifies some implications of these applications	• identifies that chemical science knowledge has changed over time • identifies ways in which chemical science has been used in society to meet needs

Chemistry inquiry skills

A	B	C	D	E
For the chemical science contexts studied, the student:	*For the chemical science contexts studied, the*	*For the chemical science contexts*	*For the chemical science contexts*	*For the chemical science contexts*

Chemistry inquiry skills

	student:	*studied, the student:*	*studied, the student:*	*studied, the student:*
• designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data, and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories, and develops evidence-based conclusions that identify limitations • evaluates processes and claims, and provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies, and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories, 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 describe complex relationships and solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies, and sources of error • selects data to demonstrate relationships linked to chemical science knowledge, and provides conclusions based on data • evaluates processes and claims, and suggests improvements or alternatives • selects, constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends, and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

Unit 3: Equilibrium, acids and redox reactions

Unit Description

The idea of reversibility of reaction is vital in a variety of chemical systems at different scales, ranging from the processes that release carbon dioxide into our atmosphere to the reactions of ions within individual cells in our bodies. Processes that are reversible will respond to a range of factors and can achieve a state of dynamic equilibrium. In this unit, students investigate acid-base equilibrium systems and their applications. They use contemporary models to explain the nature of acids and bases, and their properties and uses. This understanding enables further exploration of the varying strengths of acids and bases. Students investigate the principles of oxidation and reduction reactions and the production of electricity from electrochemical cells.

Through the investigation of appropriate contexts, students explore the ways in which models and theories related to acid-base and redox reactions, and their applications, have developed over time and through interactions with social, economic, cultural and ethical considerations. They explore the ways in which chemistry contributes to contemporary debate in industrial and environmental contexts, including the use of energy, evaluation of risk and action for sustainability, and they recognise the limitations of science in providing definitive answers in different contexts.

Students use science inquiry skills to investigate the principles of dynamic chemical equilibrium and how these can be applied to chemical processes and systems. They investigate a range of electrochemical cells, including the choice of materials used and the voltage produced by these cells. Students use the pH scale to assist in making judgments and predictions about the extent of dissociation of acids and bases and about the concentrations of ions in an aqueous solution.

Learning Outcomes

By the end of this unit, students:

- understand the characteristics of equilibrium systems, and explain and predict how they are affected by changes to temperature, concentration and pressure
- understand the difference between the strength and concentration of acids, and relate this to the principles of chemical equilibrium
- understand how redox reactions, galvanic and electrolytic cells are modelled in terms of electron transfer
- understand how models and theories have developed over time and the ways in which chemical knowledge interacts with social, economic, cultural and political considerations in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into the properties of acids and bases, redox reactions and electrochemical cells, including volumetric analysis
- evaluate, with reference to empirical evidence, claims about equilibrium systems and justify evaluations
- communicate, predict and explain chemical phenomena using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Chemistry Unit 3)

Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSCH074)

Design investigations, including the procedure/s 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 (ACSCH075)

Conduct investigations, including using volumetric analysis techniques and constructing electrochemical cells, safely, competently and methodically for the collection of valid and reliable data (ACSCH076)

Represent data in meaningful and useful ways, including using appropriate graphic representations and correct units and symbols; organise and process data to identify trends, patterns and relationships; identify and distinguish between random and systematic errors, and estimate their effect on measured results; discuss how the nature of the procedure and the sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSCH077)

Interpret a range of scientific texts, and evaluate processes, claims and conclusions by considering the quality of available evidence, including confidence intervals in secondary data; and use reasoning to construct scientific arguments (ACSCH078)

Select, construct and use appropriate representations, including half-equations, balanced chemical equations, equilibrium constants and expressions, pH, oxidation numbers, standard electrode potentials and cell diagrams, to communicate conceptual understanding, solve problems and make predictions (ACSCH079)

Select and use appropriate mathematical representations to solve problems and make predictions, including calculating cell potentials under standard conditions, using the mole concept to calculate moles, mass, volume and concentrations from volumetric analysis data, determining the yield of incomplete reactions, and calculating the pH of solutions of strong acids and bases (ACSCH080)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSCH081)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSCH082)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSCH083)

The acceptance of scientific knowledge can be influenced by the social, economic, and cultural context in which it is considered (ACSCH084)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSCH085)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSCH086)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSCH087)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSCH088)

Science Understanding

Chemical equilibrium systems

Chemical systems may be open or closed and include physical changes and chemical reactions which can result in observable changes to the system (ACSCH089)

All physical changes are reversible, whereas only some chemical reactions are reversible (ACSCH090)

Over time, physical changes and reversible chemical reactions reach a state of dynamic equilibrium in a closed system, with the relative concentrations of products and reactants defining the position of equilibrium (ACSCH091)

The reversibility of chemical reactions can be explained by considering the activation energies of the forward and reverse reactions (ACSCH092)

The effect of changes of temperature on chemical systems at equilibrium can be explained by considering the enthalpy changes for the forward and reverse reactions (ACSCH093)

The effect of changes of concentration and pressure on chemical systems at equilibrium can be explained and predicted by applying collision theory to the forward and reverse reactions (ACSCH094)

The effects of changes of temperature, concentration of chemicals and pressure on equilibrium systems can be predicted using Le Chatelier’s Principle (ACSCH095)

Equilibrium position can be predicted qualitatively using equilibrium constants (ACSCH096)

Acids are substances that can act as proton (hydrogen ion) donors and can be classified as monoprotic or polyprotic depending on the number of protons donated by each molecule of the acid (ACSCH097)

The strength of acids is explained by the degree of ionisation at equilibrium in aqueous solution, which can be represented with chemical equations and equilibrium constants (Ka) (ACSCH098)

The relationship between acids and bases in equilibrium systems can be explained using the Brønsted-Lowry model and represented using chemical equations that illustrate the transfer of hydrogen ions (ACSCH099)

The pH scale is a logarithmic scale and the pH of a solution can be calculated from the concentration of hydrogen ions; K_w can be used to calculate the concentration of hydrogen ions from the concentration of hydroxide ions in a solution (ACSCH100)

Acid-base indicators are weak acids or bases where the acidic form is of a different colour to the basic form (ACSCH101)

Volumetric analysis methods involving acid-base reactions rely on the identification of an equivalence point by measuring the associated change in pH, using chemical indicators or pH meters, to reveal an observable end point (ACSCH102)

Oxidation and reduction

A range of reactions, including displacement reactions of metals, combustion, corrosion, and electrochemical processes, can be modelled as redox reactions involving oxidation of one substance and reduction of another substance (ACSCH103)

Oxidation can be modelled as the loss of electrons from a chemical species, and reduction can be modelled as the gain of electrons by a chemical species; these processes can be represented using half-equations (ACSCH104)

The ability of an atom to gain or lose electrons can be explained with reference to valence electrons, consideration of energy, and the overall stability of the atom, and can be predicted from the atom's position in the periodic table (ACSCH105)

The relative strength of oxidising and reducing agents can be determined by comparing standard electrode potentials (ACSCH106)

Electrochemical cells, including galvanic and electrolytic cells, consist of oxidation and reduction half-reactions connected via an external circuit that allows electrons to move from the anode (oxidation reaction) to the cathode (reduction reaction) (ACSCH107)

Galvanic cells, including fuel cells, generate an electrical potential difference from a spontaneous redox reaction; they can be represented as cell diagrams including anode and cathode half-equations (ACSCH108)

Fuel cells can use metal nanoparticles as catalysts to improve the efficiency of energy production (ACSCH109)

Cell potentials at standard conditions can be calculated from standard electrode potentials; these values can be used to compare cells constructed from different materials (ACSCH110)

Electrolytic cells use an external electrical potential difference to provide the energy to allow a non-spontaneous redox reaction to occur, and can be used in small-scale and industrial situations (ACSCH111)

Chemistry

Unit 4: Structure, synthesis and design

Unit Description

Current and future applications of chemistry include the development of specialised techniques to create, or synthesise, new substances to meet the specific needs of society, including pharmaceuticals, fuels, polymers and nanomaterials. In this unit, students focus on the principles and application of chemical synthesis, particularly in organic chemistry. This involves considering where and how functional groups can be incorporated into already existing carbon compounds in order to generate new substances with properties that enable them to be used in a range of contexts.

Through the investigation of appropriate contexts, students explore the ways in which models and theories related to chemical synthesis, structure and design, and associated applications, have developed over time and through interactions with social, economic, cultural and ethical considerations. They explore the ways in which chemistry contributes to contemporary debate regarding current and future uses of local, regional and international resources, evaluation of risk and action for sustainability, and they recognise the limitations of science in providing definitive answers in different contexts.

Students use science inquiry skills to investigate the principles and application of chemical structure, synthesis and design. They select and use data from instrumental analysis to determine the identity and structure of a range of organic materials. They make predictions based on knowledge of types of chemical reactions, and investigate chemical reactions qualitatively and quantitatively.

Learning Outcomes

By the end of this unit, students:

- understand how the presence of functional groups and the molecular structure of organic compounds are related to their properties
- understand addition, condensation and oxidation reactions, and predict the products of these reactions
- understand how knowledge of chemical systems is used to design synthesis processes, and how data from analytical techniques provides information about chemical structure
- understand how models and theories have developed over time and the ways in which chemical knowledge interacts with social, economic, cultural and ethical considerations in a range of contexts
- use science inquiry skills to design, conduct, evaluate and communicate investigations into reactions and the identification of organic compounds, including analysis of secondary data derived from chemical analysis
- evaluate, with reference to empirical evidence, claims about organic synthesis and chemical design, and justify evaluations
- communicate, predict and explain chemical phenomena using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Chemistry Unit 4)

Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSCH112)

Design investigations, including the procedure/s 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 (ACSCH113)

Conduct investigations, including using organic synthesis methods and collating data from chemical analyses, safely, competently and methodically for the collection of valid and reliable data (ACSCH114)

Represent data in meaningful and useful ways, including using appropriate graphic representations and correct units and symbols; organise and analyse data to identify patterns and relationships; identify and distinguish between random and systematic errors, and estimate their effect on measured results; discuss how the nature of the procedure and the sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence from a range of sources to make and justify conclusions (ACSCH115)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSCH116)

Select, construct and use appropriate representations, including physical, virtual and graphical models of primary, secondary and tertiary structures, structural formulas, chemical equations, systematic nomenclature (using IUPAC conventions) and spectra, to communicate conceptual understanding, solve problems and make predictions (ACSCH117)

Select and use appropriate mathematical representations to solve problems and make predictions, including using the mole concept to calculate quantities in chemical reactions, including multi-step reactions, and the percentage yield of synthesis reactions (ACSCH118)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSCH119)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSCH120)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSCH121)

The acceptance of scientific knowledge can be influenced by the social, economic and cultural context in which it is considered (ACSCH122)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSCH123)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSCH124)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSCH125)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSCH126)

Science Understanding

Properties and structure of organic materials

Organic molecules have a hydrocarbon skeleton and can contain functional groups, including alcohols, carboxylic acids, esters, amines and amides (ACSCH127)

Each class of organic compounds displays characteristic chemical properties and undergoes specific reactions based on the functional groups present; these reactions, including acid-base and oxidation reactions, can be used to identify the class of the organic compound (ACSCH128)

Organic materials including proteins, carbohydrates and synthetic polymers display properties including strength, density and biodegradability that can be explained by considering the primary, secondary or tertiary structures of the material (ACSCH129)

Data from analytical techniques, including mass spectrometry, x-ray crystallography and infrared spectroscopy, can be used to determine the structure of organic molecules, often using evidence from more than one technique (ACSCH130)

Chemical synthesis and design

Chemical synthesis involves the selection of particular reagents to form a product with specific properties (for example, pharmaceuticals, fuels, cosmetics, cleaning products) (ACSCH131)

Designing chemical synthesis processes involves constructing reaction pathways that may include more than one chemical reaction (ACSCH132)

Designing chemical synthesis processes includes identifying reagents and reaction conditions in order to maximise yield and purity of product (ACSCH133)

The yield of a chemical synthesis reaction can be calculated by comparing stoichiometric quantities with actual quantities (ACSCH134)

Green chemistry principles include the design of chemical synthesis processes that use renewable raw materials, limit the use of potentially harmful solvents and minimise the amount of unwanted products (ACSCH135)

Organic molecules, including polymers, can be synthesised using addition and condensation reactions (ACSCH136)

Fuels (for example, biodiesel, ethanol, hydrogen) can be synthesised from organic or inorganic sources using a range of chemical reactions including addition, oxidation and esterification (ACSCH137)

Molecular manufacturing processes, including protein synthesis, involve the positioning of molecules to facilitate a specific chemical reaction; such methods have the potential to synthesise specialised products (for example, carbon nanotubes, nanorobots, chemical sensors used in medicine) (ACSCH138)

Units 3 and 4 Achievement Standards

Chemistry concepts, models and applications

A	B	C	D	E
For the chemical systems studied, the student:	*For the chemical systems studied, the student:*	*For the chemical systems studied, the*	*For the chemical systems studied, the*	*For the chemical systems studied,*

Chemistry concepts, models and applications

		student:	*student:*	*the student:*

Chemistry concepts, models and applications

• analyses how a range of interrelated factors affect atomic and molecular interactions and change the structure, properties and dynamics of chemical systems • analyses how interactions between matter and energy in complex chemical systems can be designed, monitored and controlled to produce desired outcomes • explains the theories and model/s used to explain the system, the supporting evidence, and their limitations and assumptions • applies theories and models of systems and processes to explain phenomena, critically analyse complex problems, and make reasoned, plausible predictions in unfamiliar contexts *For the chemical science contexts studied, the student:*	• explains how a range of interrelated factors change the structure, properties and dynamics of chemical systems • explains how interactions between matter and energy in chemical systems can be designed, monitored and controlled to produce desired outcomes • describes the theories and model/s used to explain the system, some supporting evidence, and their limitations • applies theories and models of systems and processes to explain phenomena, analyse problems, and make plausible	• explains how a range of factors change the structure, properties and dynamics of chemical systems • describes how chemical systems are controlled and monitored to produce desired outcomes • describes key aspects of a theory or model used to explain system processes, and the phenomena to which those processes can be applied • applies theories or models of systems and processes to explain phenomena, interpret problems, and make plausible	• describes how some factors affect the properties of chemical systems • describes how chemical systems are manipulated to produce desired outcomes • describes key aspects of a theory or model used to explain a system process • describes phenomena, interprets simple problems, and makes predictions in familiar contexts *For the chemical science contexts studied, the student:* • describes the roles of	• describes changes to chemical systems • describes how chemical systems are used to produce desired outcomes • identifies aspects of a theory or model related to a system process • describes phenomena and makes simple predictions in familiar contexts *For the chemical science contexts studied, the student:* • identifies that chemical science

Chemistry concepts, models and applications

• analyses the roles of collaboration, debate and review, and technologies, in the development of chemical science theories and models • evaluates how chemical science has been used in concert with other sciences to meet diverse needs and inform decision making, and how these applications are influenced by interacting social, economic and ethical factors	predictions in unfamiliar contexts *For the chemical science contexts studied, the student:* • explains the roles of collaboration, debate and review, and technologies, in the development of chemical science theories and models • explains how chemical science has been used to meet diverse needs and inform decision making, and how these applications are influenced by social, economic and ethical factors	predictions in some unfamiliar contexts *For the chemical science contexts studied, the student:* • describes the roles of collaboration and review, and technologies, in the development of chemical science theories or models • discusses how chemical science has been used to meet needs and inform decision making, and some social, economic or ethical implications of these applications	communication and new evidence in developing chemical science knowledge • describes ways in which chemical science has been used in society to meet needs, and identifies some implications of these applications	knowledge has changed over time • identifies ways in which chemical science has been used in society to meet needs

Chemistry inquiry skills

A	B	C	D	E
For the chemical science contexts studied, the student:	*For the chemical science contexts studied, the*	*For the chemical science contexts*	*For the chemical science contexts*	*For the chemical science contexts*

Chemistry inquiry skills

	student:	studied, the student:	studied, the student:	studied, the student:
• designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data, and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories, and develops evidence-based conclusions that identify limitations • evaluates processes and claims, and provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies, and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories, 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 describe complex relationships and solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies, and sources of error • selects data to demonstrate relationships linked to chemical science knowledge, and provides conclusions based on data • evaluates processes and claims, and suggests improvements or alternatives • selects , constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends, and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

Chemistry Glossary

Algebraic representation
A set of symbols linked by mathematical operations; the set of symbols summarise relationships between variables.

Animal ethics
Animal ethics involves consideration of respectful, fair and just treatment of animals. The use of animals in science involves consideration of replacement (substitution of insentient materials for conscious living animals), reduction (using only the minimum number of animals to satisfy research statistical requirements) and refinement (decrease in the incidence or severity of 'inhumane' procedures applied to those animals that still have to be used).

Anomalous data
Data that does not fit a pattern; outlier.

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.

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.

Genre
The categories into which texts are grouped; genre distinguishes texts on the basis of their subject matter, form and structure (for example, scientific reports, field guides, explanations, procedures, biographies, media articles, persuasive texts, narratives).

Green chemistry
Chemistry that aims to design products and processes that minimise the use and generation of hazardous substances and wastes. Principles of green chemistry include prevention of waste; atom economy; design of less toxic chemicals and synthesis methods; use of safer solvents and auxiliaries; design for energy efficiency; use of renewable feedstocks; reduction of unnecessary derivatives; use of catalytic reagents rather than stoichiometric reagents; design for degradation; design of in-process analysis for pollution prevention; and safer chemistry for accident prevention.

Hypothesis
A tentative explanation for an observed phenomenon, expressed as a precise and unambiguous statement 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. Investigations can include observation, research, field work, laboratory experimentation and manipulation of simulations.

Law

A statement describing invariable relationships between phenomena in specified conditions, frequently expressed mathematically.

Measurement error

The difference between the measurement result and a currently accepted or standard value of a quantity.

Media texts

Spoken, print, graphic or electronic communications with a public audience. Media texts can be found in newspapers, magazines and on television, film, radio, computer software and the internet.

Mode

The various processes of communication – listening, speaking, reading/viewing and writing/creating.

Model

A representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea.

Primary data

Data collected directly by a person or group

Primary source

Report of data created by the person or persons directly involved in observations of one or more events, experiments, investigations or projects.

Random error

Uncontrollable effects of the measurement equipment, procedure and environment on a measurement result; the magnitude of random error for a measurement result can be estimated by finding the spread of values around the average of independent, repeated measurements of the quantity.

Reliability

The degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

Reliable data

Data that has been judged to have a high level of reliability; reliability is the degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

Representation

A verbal, visual, physical or mathematical demonstration of understanding of a science concept or concepts. A concept can be represented in a range of ways and using multiple modes.

Research

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

Research ethics

Norms of conduct that determine ethical research behavior; research ethics are governed by principles such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics.

Risk assessment

Evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities. Requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate.

Secondary data

Data collected by a person or group other than the person or group using the data.

Secondary source

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

Significant figures

The use of place value to represent a measurement result accurately and precisely.

Simulation

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

System

A group of interacting objects, materials or processes that form an integrated whole. Systems can be open or closed.

Systematic error

The contribution to the uncertainty in a measurement result that is identifiable and quantifiable, for example, imperfect calibration of measurement instruments.

Theory

A set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena. Theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power.

Uncertainty

Range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment.

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.

The Australian Curriculum
Earth and Environmental Science

Earth and Environmental Science

Rationale and Aims

Rationale

Earth and Environmental Science is a multifaceted field of inquiry that focuses on interactions between the solid Earth, its water, its air and its living organisms, and on dynamic, interdependent relationships that have developed between these four components. Earth and environmental scientists consider how these interrelationships produce environmental change at a variety of timescales. To do this, they integrate knowledge, concepts, models and methods drawn from geology, biology, physics and chemistry in the study of Earth's ancient and modern environments. Earth and environmental scientists strive to understand past and present processes so that reliable and scientifically-defensible predictions can be made about the future.

Earth and Environmental Science builds on the content in the Biological and Earth and Space Sciences sub-strands of the Foundation to Year 10 Australian Curriculum: Science. In particular, the subject provides students with opportunities to explore the theories and evidence that frame our understanding of Earth's origins and history; the dynamic and interdependent nature of Earth's processes, environments and resources; and the ways in which these processes, environments and resources respond to change across a range of temporal and spatial scales.

In this subject, the term 'environment' encompasses terrestrial, marine and atmospheric settings and includes Earth's interior. Environments are described and characterised with a focus on systems thinking and multidisciplinarity rather than with a particular ecological, biological, physical or chemical focus. This subject emphasises the way Earth materials and processes generate environments including habitats where organisms live; the natural processes and human influences which induce changes in physical environments; and the ways in which organisms respond to those changes.

Studying senior secondary Science provides students with a suite of skills and understandings that are valuable to a wide range of further study pathways and careers. In this subject, students develop their investigative, analytical and communication skills and apply these to their understanding of science issues in order to engage in public debate, solve problems and make evidence-based decisions about contemporary issues. The knowledge, understanding and skills introduced in this subject will encourage students to become confident, active citizens who can competently use diverse methods of inquiry, and will provide a foundation for further studies or employment in Earth and environmental science-related fields.

Aims

Earth and Environmental Science aims to develop students':

- interest in Earth and environmental science and their appreciation of how this multidisciplinary knowledge can be used to understand contemporary issues
- understanding of Earth as a dynamic planet consisting of four interacting systems: the geosphere, atmosphere, hydrosphere and lithosphere
- appreciation of the complex interactions, involving multiple parallel processes, that continually change Earth systems over a range of timescales
- understanding that Earth and environmental science knowledge has developed over time; is used in a variety of contexts; and influences, and is influenced by, social, economic, cultural and ethical considerations
- ability to conduct a variety of field, research and laboratory investigations involving collection and analysis of qualitative and quantitative data, and interpretation of evidence
- ability to critically evaluate Earth and environmental science concepts, interpretations, claims and conclusions with reference to evidence
- ability to communicate Earth and environmental understanding, findings, arguments and conclusions using appropriate representations, modes and genres.

Earth and Environmental Science

Organisation

Overview of the senior secondary Australian Curriculum

ACARA has developed senior secondary Australian Curriculum for English, Mathematics, Science and History according to a set of design specifications. The ACARA Board approved these specifications following consultation with state and territory curriculum, assessment and certification authorities.

The senior secondary Australian Curriculum specifies 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) expected of 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 and examinations). 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 their courses. They 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 local courses that integrate the Australian Curriculum content and achievement standards and any additional information, guidelines and rules to satisfy local requirements including advice on entry and exit points and credit for completed study.

The senior secondary Australian Curriculum for each subject should not, therefore, be read as a course of study. Rather, it is presented as content and achievement standards for integration into state and territory courses.

Senior secondary Science subjects

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

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

Structure of Earth and Environmental Science

Units

In Earth and Environmental Science, students develop their understanding of the ways in which interactions between Earth systems influence Earth processes, environments and resources. There are four units:

- Unit 1: Introduction to Earth systems
- Unit 2: Earth processes - energy transfers and transformations
- Unit 3: Living on Earth - extracting, using and managing Earth resources
- Unit 4: The changing Earth - the cause and impact of Earth hazards.

In Units 1 and 2, students are introduced to the Earth system model and to the ways in which the Earth spheres interact and are related by transfers and transformations of energy. In Unit 1, students examine the evidence underpinning theories of the development of the Earth systems, their interactions and their components. In Unit 2, students investigate how Earth processes involve interactions of Earth systems and are inter-related through transfers and transformations of energy.

In Units 3 and 4, students use the Earth system model and an understanding of Earth processes, to examine Earth resources and environments, as well as the factors that impact the Earth system at a range of spatial and temporal scales. In Unit 3, students examine renewable and non-renewable resources, the implications of extracting, using and consuming these resources, and associated management approaches. In Unit 4, students consider how Earth processes and human activity can contribute to Earth hazards, and the ways in which these hazards can be predicted, managed and mitigated to reduce their impact on Earth environments.

Each unit includes:

- Unit descriptions – short descriptions of the purpose of and rationale for each unit
- Learning outcomes – six to eight statements describing the learning expected as a result of studying the unit
- Content descriptions – descriptions of the core content to be taught and learned, organised into three strands:
  - *Science Inquiry Skills*
  - *Science as a Human Endeavour*
  - *Science Understanding (organised in sub-units).*

Organisation of content

Science strand descriptions

The Australian Curriculum: Science has three interrelated strands: *Science Inquiry Skills, Science as a Human Endeavour* and *Science Understanding*. These strands are used to organise the Science learning area from Foundation to Year 12. In the senior secondary Science subjects, the three strands build on students' learning in the F-10 Australian Curriculum: Science.

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. Students' experiences of school science should mirror 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 for *Science Inquiry Skills*, *Science as a Human Endeavour* and *Science Understanding* have been written so that this integration is possible in each unit.

Science Inquiry Skills

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

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

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

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 more specific skills to be taught within the 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:

- Identifying, researching and constructing questions for investigation; proposing hypotheses; and predicting possible outcomes
- Designing investigations, including the procedure/s 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
- Conducting investigations, including using equipment and techniques safely, competently and methodically for the collection of valid and reliable data
- Representing data in meaningful and useful ways; organising and analysing data to identify trends, patterns and relationships; recognising error, uncertainty and limitations in data; and selecting, synthesising and using evidence to construct and justify conclusions
- Interpreting scientific and media texts and evaluating processes, claims and conclusions by considering the quality of available evidence; and using reasoning to construct scientific arguments
- Selecting, constructing and using appropriate representations to communicate understanding, solve problems and make predictions
- Communicating to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes.

The senior secondary Science subjects have been designed to accommodate, if appropriate, an extended scientific investigation within 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.

Science as a Human Endeavour

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

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

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

Across the senior secondary Science subjects, the same set of *Science as a Human Endeavour* content descriptions is used for Units 1 and 2 of the subjects; and another set for Units 3 and 4. This consistent approach enables students to develop a rich appreciation of the complex ways in which science interacts with society, through the exploration of *Science as a Human Endeavour* concepts across the subjects and in multiple contexts.

'*Examples in context*' will be developed to illustrate possible contexts related to *Science Understanding* content, in which students could explore *Science as a Human Endeavour* concepts. These will be made available to complement the final online curriculum. Each *Example in context* will be aligned to the relevant sub-unit in Science Understanding and will include links to the relevant *Science as a Human Endeavour* content descriptions.

Science Understanding

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

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

Science understanding can be developed through the selection of contexts that have relevance to and are engaging for students. The Australian Curriculum: Science has been designed to provide jurisdictions, schools and teachers with the flexibility to select contexts that meet the social, geographic and learning needs of their students.

Organisation of achievement standards

The Earth and Environmental Science achievement standards are organised by two dimensions: 'Earth and Environmental Science Concepts, Models and Applications' and 'Earth and Environmental Science Inquiry Skills'. They describe five levels of student achievement.

'Earth and Environmental Science 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. 'Earth and Environmental Science Inquiry Skills' describes the skills students demonstrate when investigating the content developed through the strands of *Science Understanding* and *Science as a Human Endeavour*.

Senior secondary achievement standards have been written for each Australian Curriculum senior secondary subject. The achievement standards provide an indication of typical performance at five different levels (corresponding to grades A to E) following the completion of study of senior secondary Australian Curriculum content for a pair of units. They are broad statements of understanding and skills that are best read and understood in conjunction with the relevant unit content. They are structured to reflect key dimensions of the content of the relevant learning area. They will be eventually accompanied by illustrative and annotated samples of student work/ performance/ responses.

The achievement standards will be refined empirically through an analysis of samples of student work and responses to assessment tasks: they cannot be maintained *a priori* without reference to actual student performance. Inferences can be drawn about the quality of student learning on the basis of observable differences in the extent, complexity, sophistication and generality of the understanding and skills typically demonstrated by students in response to well-designed assessment activities and tasks.

In the short term, achievement standards will inform assessment processes used by curriculum, assessment and certifying authorities for course offerings based on senior secondary Australian Curriculum content.

ACARA has made reference to a common syntax (as a guide, not a rule) in constructing the achievement standards across the learning areas. The common syntax that has guided development is as follows:

- Given a specified context (as described in the curriculum content)
- With a defined level of consistency/accuracy (the assumption that each level describes what the student does well, competently, independently, consistently)
- Students perform a specified action (described through a verb)
- In relation to what is valued in the curriculum (specified as the object or subject)
- With a defined degree of sophistication, difficulty, complexity (described as an indication of quality)

Terms such as 'analyse' and 'describe' have been used to specify particular action but these can have everyday meanings that are quite general. ACARA has therefore associated these terms with specific meanings that are defined in the senior secondary achievement standards glossary and used precisely and consistently across subject areas.

Links to Foundation to Year 10

Progression from the F-10 Australian Curriculum: Science

The Earth and Environmental Science curriculum continues to develop student understanding and skills from across the three strands of the F-10 Australian Curriculum: Science.

In the *Science Understanding* strand, the Earth and Environmental Science curriculum draws on knowledge and understanding from across the four sub-strands of Biological, Physical, Chemical and Earth and Space Sciences. In particular, the Earth and Environmental Science curriculum continues to develop the key concepts introduced in the Biological Sciences and Earth and Space Sciences sub-strands, that is, that a diverse range of living things have evolved on Earth over hundreds of millions of years; that living things are interdependent and interact with each other and with their environment; and that the Earth is subject to change within and on its surface, over a range of timescales as a result of natural processes and human use of resources.

Mathematical skills expected of students studying Earth and Environmental Science

The Earth and Environmental Science 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 arguments, claims or conclusions.. In gathering and recording numerical data, students are required to make measurements with an appropriate degree of accuracy and to represent measurements using appropriate units.

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

It is assumed that students will be able to competently:

- perform calculations involving addition, subtraction, multiplication and division of quantities
- perform approximate evaluations of numerical expressions
- express fractions as percentages, and percentages as fractions
- calculate percentages

- recognise and use ratios
- transform decimal notation to power of ten notation
- substitute physical quantities into an equation using consistent units so as to calculate one quantity and check the dimensional consistency of such calculations
- solve simple algebraic equations
- comprehend and use the symbols/notations $<$,$>$, Δ, $\approx$
- translate information between graphical, numerical and algebraic forms
- distinguish between discrete and continuous data and then select appropriate forms, variables and scales for constructing graphs
- construct and interpret frequency tables and diagrams, pie charts and histograms
- describe and compare data sets using mean, median and inter-quartile range
- interpret the slope of a linear graph.

Representation of General capabilities

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

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

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

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

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

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

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

Representation of Cross-curriculum priorities

While the significance of the cross-curriculum priorities for Earth and Environmental Science varies, there are opportunities for teachers to select contexts that incorporate the key concepts from each priority.

The Earth and Environmental Science curriculum provides an opportunity for students to engage with *Aboriginal and Torres Strait Islander histories and cultures*. It acknowledges that Aboriginal and Torres Strait Islander people have longstanding scientific knowledge traditions that inform understanding of the Australian environment and the ways in which it has changed over time. In exploring scientific knowledge and decision making about Earth processes, environments and resources, students could develop an understanding that Aboriginal and Torres Strait Islander people have particular ways of knowing the world and continue to be innovative in providing significant contributions to development in science. Students could investigate examples of Aboriginal and Torres Strait Islander science and the ways traditional knowledge and Western scientific knowledge can be complementary.

Students could investigate a wide range of contexts that draw *on Asia and Australia's engagement with Asia* through Earth and Environmental Science. Students could explore the diverse environments of the Asia region and develop an appreciation that interaction between human activity and these environments continues to influence the region, including Australia, and has significance for the rest of the world. Through an examination of developments in Earth and Environmental Science, students could appreciate that the Asia region plays an important role in scientific research and development, including through collaboration with Australian scientists, in such areas as natural hazard prediction and management, natural resource management, energy security and food security.

The *Sustainability* priority is explicitly addressed in Earth and Environmental Science. The Earth system model that frames the curriculum requires students to understand the interconnectedness of Earth's biosphere, geosphere, hydrosphere and atmosphere and how these systems operate and interact across a range of spatial and temporal scales. Relationships including cycles and cause and effect are explored, and students develop skills of observation and analysis to examine these relationships in the world around them now and into the future.

In Earth and Environmental Science, students appreciate that Earth and environmental science provides the basis for decision making in many areas of society and that these decisions can impact the Earth system, its environments and its resources. 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 and provide for a more sustainable future.

Safety

Science learning experiences may involve the use of potentially hazardous substances and/or hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students and that school practices meet the requirements of the Work Health and Safety Act 2011, in addition to relevant state 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.

Animal ethics

Through a consideration of research ethics as part of *Science Inquiry Skills*, students will examine their own ethical position, draw on ethical perspectives when designing investigation methods, and ensure that any activities that impact on living organisms comply with the *Australian code of practice for the care and use of animals for scientific purposes 7th edition* (2004) (http://www.nhmrc.gov.au/guidelines/publications/ea16) .

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*, in addition to relevant state or territory guidelines.

When state and territory curriculum authorities integrate the Australian Curriculum into local courses, they will include more specific advice on the care and use of, or interaction with, animals.

For further information about relevant guidelines or to access your local Animal Ethics Committee, contact your state or territory curriculum authority.

Unit 1: Introduction to Earth systems

Unit Description

The Earth system involves four interacting systems: the geosphere, atmosphere, hydrosphere and biosphere. A change in any one 'sphere' can impact others at a range of temporal and spatial scales. In this unit, students build on their existing knowledge of Earth by exploring the development of understanding of Earth's formation and its internal and surface structure. Students study the processes that formed the oceans and atmosphere. They review the origin and significance of water at Earth's surface, how water moves through the hydrological cycle, and the environments influenced by water, in particular the oceans, the cryosphere and groundwater. Students will examine the formation of soils at Earth's surface (the pedosphere) as a process that involves the interaction of all Earth systems.

Students critically examine the scientific evidence for the origin of life, linking this with their understanding of the evolution of Earth's hydrosphere and atmosphere. They review evidence from the fossil record that demonstrates the interrelationships between major changes in Earth's systems and the evolution and extinction of organisms. They investigate how the distribution and viability of life on Earth influences, and is influenced by, Earth systems.

Through the investigation of appropriate contexts, students explore how international collaboration, evidence from multiple disciplines and individuals and the development of ICT and other technologies have contributed to developing understanding of Earth systems. They investigate how scientific knowledge is used to offer valid explanations and reliable predictions, and the ways in which it interacts with social, economic and cultural factors.

Students use science inquiry skills that mirror the types of inquiry conducted to establish our contemporary understanding of Earth systems: they engage in a range of investigations that help them develop the field and research skills used by geoscientists, soil scientists, atmospheric scientists, hydrologists, ecologists and environmental chemists to interpret geological, historical and real-time scientific information.

Learning Outcomes

By the end of this unit, students:

- understand the key features of Earth systems, how they are interrelated, and their collective 4.5 billion year history
- understand scientific models and evidence for the structure and development of the solid Earth, the hydrosphere, the atmosphere and the biosphere
- understand how theories and models have developed based on evidence from multiple disciplines; and the uses and limitations of Earth and environmental science knowledge in a range of contexts
- use science inquiry skills to collect, analyse and communicate primary and secondary data on Earth and environmental phenomena; and use these as analogues to deduce and analyse events that occurred in the past
- evaluate, with reference to empirical evidence, claims about the structure, interactions and evolution of Earth systems
- communicate Earth and environmental understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Earth and Environmental Science Unit 1)

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSES001)

Design investigations including the procedure/s to be followed, the information required and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics (ACSES002)

Conduct investigations, including using map and field location techniques and rock and soil sampling and identification procedures, safely, competently and methodically for the collection of valid and reliable data (ACSES003)

Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; qualitatively describe sources of measurement error, and uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSES004)

Interpret a range of scientific and media texts and evaluate processes, claims and conclusions by considering the quality of available evidence; use reasoning to construct scientific arguments (ACSES005)

Select, construct and use appropriate representations, including maps and cross sections to describe and analyse spatial relationships, and stratigraphy and isotopic half-life data to infer the age of rocks and fossils, to communicate conceptual understanding, solve problems and make predictions (ACSES006)

Communicate to specific audiences and for specific purposes using appropriate language, genres and modes, including compilations of field data and research reports (ACSES007)

Science as a Human Endeavour (Units 1 & 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSES008)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSES009)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSES010)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSES011)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSES012)

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSES013)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSES014)

Science Understanding

Development of the geosphere

Observation of present day processes can be used to infer past events and processes by applying the Principle of Uniformitarianism (ACSES015)

A relative geological time scale can be constructed using stratigraphic principles including superposition, cross cutting relationships, inclusions and correlation (ACSES016)

Precise dates can be assigned to points on the relative geological time scale using data derived from the decay of radioisotopes in rocks and minerals; this establishes an absolute time scale and places the age of the Earth at 4.5 billion years (ACSES017)

Earth has internally differentiated into a layered structure: a solid metallic inner core, a liquid metallic outer core and a silicate mantle and crust; the study of seismic waves and meteorites provides evidence for this structure (ACSES018)

Rocks are composed of characteristic assemblages of mineral crystals or grains that are formed through igneous, sedimentary and metamorphic processes, as part of the rock cycle (ACSES019)

Soil formation requires interaction between atmospheric, geologic, hydrologic and biotic processes; soil is composed of rock and mineral particles, organic material, water, gases and living organisms (ACSES020)

Development of the atmosphere and hydrosphere

The atmosphere was derived from volcanic outgassing during cooling and differentiation of Earth and its composition has been significantly modified by the actions of photosynthesising organisms (ACSES021)

The modern atmosphere has a layered structure characterised by changes in temperature: the troposphere, mesosphere, stratosphere and thermosphere (ACSES022)

Water is present on the surface of Earth as a result of volcanic outgassing and impact by icy bodies from space; water occurs in three phases (solid, liquid, gas) on Earth's surface (ACSES023)

Water's unique properties, including its boiling point, density in solid and liquid phase, surface tension and its ability to act a solvent, and its abundance at the surface of Earth make it an important component of Earth system processes (for example, precipitation, ice sheet formation, evapotranspiration, solution of salts) (ACSES024)

Development of the biosphere

Fossil evidence indicates that life first appeared on Earth approximately 4 billion years ago (ACSES025)

Laboratory experimentation has informed theories that life emerged under anoxic atmospheric conditions in an aqueous mixture of inorganic compounds, either in a shallow water setting as a result of lightning strike or in an ocean floor setting due to hydrothermal activity (ACSES026)

In any one location, the characteristics (for example, temperature, surface water, substrate, organisms, available light) and interactions of the atmosphere, geosphere, hydrosphere and biosphere give rise to unique and dynamic communities (ACSES027)

The characteristics of past environments and communities (for example, presence of water, nature of the substrate, organism assemblages) can be inferred from the sequence and internal textures of sedimentary rocks and enclosed fossils (ACSES028)

The diversification and proliferation of living organisms over time (for example, increases in marine animals in the Cambrian), and the catastrophic collapse of ecosystems (for example, the mass extinction event at the end of the Cretaceous) can be inferred from the fossil record (ACSES029)

Unit 2: Earth processes – energy transfers and transformations

Unit Description

Earth system processes require energy. In this unit, students explore how the transfer and transformation of energy from the sun and Earth's interior enable and control processes within and between the geosphere, atmosphere, hydrosphere and biosphere. Students examine how the transfer and transformation of heat and gravitational energy in Earth's interior drive movements of Earth's tectonic plates. They analyse how the transfer of solar energy to Earth is influenced by the structure of the atmosphere; how air masses and ocean water move as a result of solar energy transfer and transformation to cause global weather patterns; and how changes in these atmospheric and oceanic processes can result in anomalous weather patterns.

Students use their knowledge of the photosynthetic process to understand the transformation of sunlight into other energy forms that are useful for living things. They study how energy transfer and transformation in ecosystems are modelled and they review how biogeochemical cycling of matter in environmental systems involves energy use and energy storage.

Through the investigation of appropriate contexts, students explore how international collaboration, evidence from multiple disciplines and individuals and the development of ICT and other technologies have contributed to developing understanding of the energy transfers and transformations within and between Earth systems. They investigate how scientific knowledge is used to offer valid explanations and reliable predictions, and the ways in which it interacts with social, economic and cultural factors, including the design of action for sustainability.

Students use inquiry skills to collect, analyse and interpret data relating to energy transfers and transformations and cycling of matter and make inferences about the factors causing changes to movements of energy and matter in Earth systems.

Learning Outcomes

By the end of this unit, students:

- understand how energy is transferred and transformed in Earth systems, the factors that influence these processes, and the dynamics of energy loss and gain
- understand how energy transfers and transformations influence oceanic, atmospheric and biogeochemical cycling
- understand how theories and models have developed based on evidence from multiple disciplines; and the uses and limitations of Earth and environmental science knowledge in a range of contexts
- use science inquiry skills to collect, analyse and communicate primary and secondary data on energy transfers and transformations between and within Earth systems
- evaluate, with reference to empirical evidence, claims about energy transfers and transformations between and within Earth systems
- communicate Earth and environmental understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Earth and Environmental Science Unit 2)

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSES030)

Design investigations including the procedure/s to be followed, the information required and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics (ACSES031)

Conduct investigations, including using map and field location techniques and environmental sampling procedures, safely, competently and methodically for the collection of valid and reliable data (ACSES032)

Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; qualitatively describe sources of measurement error, and uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSES033)

Interpret a range of scientific and media texts and evaluate processes, claims and conclusions by considering the quality of available evidence; use reasoning to construct scientific arguments (ACSES034)

Select, construct and use appropriate representations, including maps and other spatial representations, diagrams and flow charts, to communicate conceptual understanding, solve problems and make predictions (ACSES035)

Communicate to specific audiences and for specific purposes using appropriate language, genres and modes, including compilations of field data and research reports (ACSES036)

Science as a Human Endeavour (Units 1 & 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSES037)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSES038)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSES039)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSES040)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSES041)

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSES042)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSES043)

Science Understanding

Energy for Earth processes

Energy is neither created nor destroyed, but can be transformed from one form to another (for example, kinetic, gravitational, thermal, light) and transferred between objects (ACSES044)

Processes within and between Earth systems require energy that originates either from the sun or the interior of Earth (ACSES045)

Thermal and light energy from the Sun drives important Earth processes including evaporation and photosynthesis (ACSES046)

Transfers and transformations of heat and gravitational energy in Earth's interior drives the movement of tectonic plates through processes including mantle convection, plume formation and slab sinking (ACSES047)

Energy for atmospheric and hydrologic processes

The net transfer of solar energy to Earth’s surface is influenced by its passage through the atmosphere, including impeded transfer of ultraviolet radiation to Earth’s surface due to its interaction with atmospheric ozone, and by the physical characteristics of Earth’s surface, including albedo (ACSES048)

Most of the thermal radiation emitted from Earth’s surface passes back out into space but some is reflected or scattered by greenhouse gases back toward Earth; this additional surface warming produces a phenomenon known as the greenhouse effect (ACSES049)

The movement of atmospheric air masses due to heating and cooling, and Earth’s rotation and revolution, cause systematic atmospheric circulation; this is the dominant mechanism for the transfer of thermal energy around Earth’s surface (ACSES050)

The behaviour of the global oceans as a heat sink, and Earth’s rotation and revolution, cause systematic ocean currents; these are described by the global ocean conveyer model (ACSES051)

The interaction between Earth’s atmosphere and oceans changes over time and can result in anomalous global weather patterns, including El Nino and La Nina (ACSES052)

Energy for biogeochemical processes

Photosynthesis is the principal mechanism for the transformation of energy from the sun into energy forms that are useful for living things; net primary production is a description of the rate at which new biomass is generated, mainly through photosynthesis (ACSES053)

The availability of energy and matter are one of the main determinants of ecosystem carrying capacity; that is, the number of organisms that can be supported in an ecosystem (ACSES054)

Biogeochemical cycling of matter, including nitrogen and phosphorus, involves the transfer and transformation of energy between the biosphere, geosphere, atmosphere and hydrosphere (ACSES055)

Energy is stored, transferred and transformed in the carbon cycle; biological elements, including living and dead organisms, store energy over relatively short timescales, and geological elements (for example, hydrocarbons, coal and kerogens) store energy for extended periods (ACSES056)

Units 1 and 2 Achievement Standards

Earth and Environmental Science concepts, models and applications

A	B	C	D	E
For the Earth systems studied, the student:	*For the Earth systems studied, the student:*	*For the Earth systems studied, the student:*	*For the Earth systems studied, the student:*	*For the Earth systems studied, the*

Earth and Environmental Science concepts, models and applications

				student:

Earth and Environmental Science concepts, models and applications

• analyses how Earth systems and their components are inter-related across a range of spatial scales, and how they have changed over time • analyses how cycling of matter and transfers and transformations of energy are interrelated within and between Earth systems across a range of temporal and spatial scales • explains the theories and model/s used to explain the system and the aspects of the system they include • applies theories and models of systems and processes to explain phenomena, interpret complex problems and make reasoned, plausible predictions in unfamiliar contexts *For the Earth and environmental contexts*	• explains how Earth system components are inter-related and how they have changed over time • explains how cycling of matter and transfers and transformations of energy occur between and within Earth systems • describes the theories and model/s used to explain the system • applies theories and models of systems and processes to explain phenomena, interpret problems and make plausible predictions in unfamiliar contexts *For the Earth and environmental contexts studied, the student:*	• describes Earth system components and how they have changed over time • describes the ways in which matter and energy move within and between Earth systems • describes a theory or model used to explain the system • applies theories or models of systems and processes to explain phenomena, interpret problems and make plausible predictions in familiar contexts *For the Earth and environmental contexts studied, the student:* • describes the role of collaboration	• identifies Earth system components • identifies processes that cause change in Earth systems • identifies aspects of a theory or model related to the system • describes phenomena, interprets simple problems and makes simple predictions in familiar contexts *For the Earth and environmental contexts studied, the student:* • describes the role of communication and new evidence in the development of Earth and environmental knowledge	• identifies some parts of the Earth system • describes some observable Earth processes • identifies aspects of a theory or model related to parts of the system • describes phenomena and makes simple predictions in familiar, simple contexts *For the Earth and environmental contexts studied, the student:* • identifies that Earth and environmental knowledge has changed over time

Earth and Environmental Science concepts, models and applications

studied, the student: • analyses the role of collaboration, debate and review, and technologies, in the development of Earth and environmental theories and models • evaluates how Earth and environmental science has been used in concert with other sciences to meet diverse needs and inform decision making; and how these applications are influenced by interacting social, economic and ethical factors	• explains the role of collaboration, debate and review, and technologies, in the development of Earth and environmental theories and models • explains how Earth and environmental science has been used to meet diverse needs and inform decision making; and how these applications are influenced by social, economic and ethical factors	and review, and technologies, in the development of Earth and environmental theories or models • discusses how Earth and environmental science has been used to meet needs and inform decision making, and some social, economic or ethical implications of these applications	• describes ways in which Earth and environmental science has been used in society to meet needs and identifies some implications of these applications	• identifies ways in which Earth and environmental science has been used in society to meet needs

Earth and Environmental Science inquiry skills

A	B	C	D	E
For the Earth and environmental contexts studied, the student:	*For the Earth and environmental contexts studied, the student:*	*For the Earth and environmental contexts studied, the student:*	*For the Earth and environmental contexts studied, the student:*	*For the Earth and environmental contexts studied, the student:*

Earth and Environmental Science inquiry skills

• designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories and develops evidence-based conclusions that identify limitations • evaluates processes and claims; provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories 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 describe complex relationships and solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies and sources of error • selects data to demonstrate relationships linked to Earth and environmental knowledge and provides conclusions based on data • evaluates processes and claims and suggests improvements or alternatives • selects, constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

Unit 3: Living on Earth - extracting, using and managing Earth resources

Unit Description

Earth resources are required to sustain life and provide infrastructure for living (for example, food, shelter, medicines, transport, and communication), driving ongoing demand for biotic, mineral and energy resources. In this unit, students explore renewable and non-renewable resources and analyse the effects that resource extraction, use and consumption and associated waste removal have on Earth systems and human communities.

Students examine the occurrence of non-renewable mineral and energy resources and review how an understanding of Earth and environmental science processes guides resource exploration and extraction. They investigate how the rate of extraction and other environmental factors impact on the quality and availability of renewable resources, including water, energy resources and biota, and the importance of monitoring and modelling to manage these resources at local, regional and global scales. Students learn about ecosystem services and how natural and human-mediated changes of the biosphere, hydrosphere, atmosphere and geosphere, including the pedosphere, influence resource availability and sustainable management.

Through the investigation of appropriate contexts, students explore the ways in which models and theories related to resource extraction, use and management have developed over time and through interactions with social, economic, cultural and ethical considerations. They investigate the ways in which science contributes to contemporary debate regarding local, regional and international resource use, evaluation of risk and action for sustainability, and recognise the limitations of science in providing definitive answers in different contexts.

Students use science inquiry skills to collect, analyse and interpret data relating to the extraction, use, consumption and waste management of renewable and non-renewable resources. They critically analyse the range of factors that determine management of renewable and non-renewable resources.

Learning Outcomes

By the end of this unit, students:

- understand the difference between renewable and non-renewable Earth resources and how their extraction, use, consumption and disposal impact Earth systems
- understand how renewable resources can be sustainably extracted, used and consumed at local, regional and global scales
- understand how models and theories have developed over time; and the ways in which Earth and environmental science knowledge interacts with social, economic, cultural and ethical considerations in a range of contexts
- use science inquiry skills to collect, analyse and communicate primary and secondary data on resource extraction and related impacts on Earth systems
- evaluate, with reference to empirical evidence, claims about resource extraction and related impacts on Earth systems and justify evaluations
- communicate Earth and environmental understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Earth and Environmental Science Unit 3)

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSES057)

Design investigations including the procedure/s to be followed, the information required and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics (ACSES058)

Conduct investigations, including using spatial analysis to complement map and field location techniques and environmental sampling procedures, safely, competently and methodically for the collection of valid and reliable data (ACSES059)

Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; discuss the ways in which measurement error and instrumental accuracy and the nature of the procedure and sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSES060)

Interpret a range of scientific and media texts and evaluate processes, claims and conclusions by considering the quality of available evidence, including interpreting confidence intervals in secondary data; use reasoning to construct scientific arguments (ACSES061)

Select, construct and use appropriate representations, including maps and other spatial representations, to communicate conceptual understanding, solve problems and make predictions (ACSES062)

Communicate to specific audiences and for specific purposes using appropriate language, genres and modes, including compilations of field data and research reports (ACSES063)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSES064)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSES065)

The acceptance of scientific knowledge can be influenced by the social, economic and cultural context in which it is considered (ACSES066)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSES067)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSES068)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSES069)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSES070)

Science Understanding

Use of non-renewable Earth resources

Non-renewable mineral and energy resources are formed over geological time scales so are not readily replenished (ACSES071)

The location of non-renewable mineral and energy resources, including fossil fuels, iron ore and gold, is related to their geological setting (for example, sedimentary basins, igneous terrains) (ACSES072)

Mineral and energy resources are discovered using a variety of remote sensing techniques (for example, satellite images, aerial photographs and geophysical datasets) and direct sampling techniques (for example, drilling, core sampling, soil and rock sampling) to identify the spatial extent of the deposit and quality of the resource (ACSES073)

The type, volume and location of mineral and energy resources influences the methods of extraction (for example, underground, open pit, onshore and offshore drilling and completion) (ACSES074)

Extraction of mineral and energy resources influences interactions between the abiotic and biotic components of ecosystems, including hydrologic systems (ACSES075)

Use of renewable Earth resources

Renewable resources are those that are typically replenished at time scales of years to decades and include harvestable resources (for example, water, biota and some energy resources) and services (for example, ecosystem services) (ACSES076)

Ecosystems provide a range of renewable resources, including provisioning services (for example, food, water, pharmaceuticals), regulating services (for example, carbon sequestration, climate control), supporting services (for example, soil formation, nutrient and water cycling, air and water purification) and cultural services (for example, aesthetics, knowledge systems) (ACSES077)

The abundance of a renewable resource and how readily it can be replenished influence the rate at which it can be sustainably used at local, regional and global scales (ACSES078)

The cost-effective use of renewable energy resources is constrained by the efficiency of available technologies to collect, store and transfer the energy (ACSES079)

The availability and quality of fresh water can be influenced by human activities (for example, urbanisation, over-extraction, pollution) and natural processes (for example, siltation, drought, algal blooms) at local and regional scales (ACSES080)

Any human activities that affect ecosystems (for example, species removal, habitat destruction, pest introduction, dryland salinity) can directly or indirectly reduce populations to beneath the threshold of population viability at local, regional and global scales and impact ecosystem services (ACSES081)

Overharvesting can directly reduce populations of biota to beneath the threshold of population viability; the concept of maximum sustainable yield aims to enable sustainable harvesting (ACSES082)

Producing, harvesting, transporting and processing of resources for consumption, and assimilating the associated wastes, involves the use of resources; the concept of an ‘ecological footprint’ is used to measure the magnitude of this demand (ACSES083)

Earth and Environmental Science

Unit 4: The changing Earth - the cause and impact of Earth hazards

Unit Description

Earth hazards occur over a range of time scales and have significant impacts on Earth systems across a wide range of spatial scales. Investigation of naturally occurring and human-influenced Earth hazards enables prediction of their impacts, and the development of management and mitigation strategies. In this unit, students examine the cause and effects of naturally occurring Earth hazards including volcanic eruptions, earthquakes and tsunami. They examine ways in which human activities can contribute to the frequency, magnitude and intensity of Earth hazards such as fire and drought. This unit focuses on the timescales at which the effects of natural and human-induced change are apparent and the ways in which scientific data are used to provide strategic direction for the mitigation of Earth hazards and environmental management decisions.

Students review the scientific evidence for climate change models, including the examination of evidence from the geological record, and explore the tensions associated with differing interpretations of the same evidence. They consider the reliability of these models for predicting climate change, and the implications of future climate change events, including changing weather patterns, globally and in Australia (for example, changes in flooding patterns or aridity, and changes to vegetation distribution, river structure and groundwater recharge).

Through the investigation of appropriate contexts, students explore the ways in which models and theories related to monitoring and managing Earth hazards and climate change have developed over time and through interactions with social, economic, cultural, and ethical considerations. They investigate the ways in which science contributes to contemporary debate regarding local, regional and international management of Earth hazards, evaluation of risk and action for sustainability, and recognise the limitations of science in providing definitive answers in different contexts.

Students use inquiry skills to collect, analyse and interpret data relating to the cause and impact of Earth hazards. They critically analyse the range of factors that influence the magnitude, frequency, intensity and management of Earth hazards at local, regional and global levels.

Learning Outcomes

By the end of this unit, students:

- understand the causes of Earth hazards and the ways in which they impact, and are impacted by, Earth systems
- understand how environmental change is modelled, and how the reliability of these models influences predictions of future events and changes
- understand how models and theories have developed over time; and the ways in which Earth and environmental science knowledge interacts with social, economic, cultural and ethical considerations in a range of contexts
- use science inquiry skills to collect, analyse and communicate primary and secondary data on Earth hazards and related impacts on Earth systems
- evaluate, with reference to empirical evidence, claims about Earth hazards and related impacts on Earth systems and justify evaluations
- communicate Earth and environmental understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills (Earth and Environmental Science Unit 4)

Identify, research and construct questions for investigation, propose hypotheses and predict possible outcomes (ACSES084)

Design investigations including the procedure/s to be followed, the information required and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics (ACSES085)

Conduct investigations, including using spatial analysis to complement map and field location techniques, environmental sampling procedures and field metering equipment, safely, competently and methodically for the collection of valid and reliable data (ACSES086)

Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; discuss the ways in which measurement error and instrumental accuracy, the nature of the procedure and sample size may influence uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions (ACSES087)

Interpret a range of scientific and media texts and evaluate processes, claims and conclusions by considering the quality of available evidence, including interpreting confidence intervals in secondary data; use reasoning to construct scientific arguments (ACSES088)

Select, construct and use appropriate representations, including maps and other spatial representations, to communicate conceptual understanding, make predictions and solve problems (ACSES089)

Communicate to specific audiences and for specific purposes using appropriate language, genres and modes, including compilations of field data and research reports (ACSES090)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of data sets with which scientists work (ACSES091)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSES092)

The acceptance of scientific knowledge can be influenced by the social, economic and cultural context in which it is considered (ACSES093)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSES094)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSES095)

International collaboration is often required when investing in large scale science projects or addressing issues for the Asia-Pacific region (ACSES096)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSES097)

Science Understanding

The cause and impact of Earth hazards

Earth hazards result from the interactions of Earth systems and can threaten life, health, property, or the environment; their occurrence may not be prevented but their effect can be mitigated (ACSES098)

Plate tectonic processes generate earthquakes, volcanic eruptions and tsunamis; the occurrence of these events affects other Earth processes and interactions (for example, ash clouds influence global weather) (ACSES099)

Monitoring and analysis of data, including earthquake location and frequency data and ground motion monitoring, allows the mapping of potentially hazardous zones, and contributes to the future prediction of the location and probability of repeat occurrences of hazardous Earth events, including volcanic eruptions, earthquakes and tsunamis (ACSES100)

Major weather systems generate cyclones, flood events and droughts; the occurrence of these events affects other Earth processes and interactions (for example, habitat destruction, ecosystem regeneration) (ACSES101)

Human activities, including land clearing, can contribute to the frequency, magnitude and intensity of some natural hazards (for example, drought, flood, bushfire, landslides) at local and regional scales (ACSES102)

The impact of natural hazards on organisms, including humans, and ecosystems depends on the location, magnitude and intensity of the hazard, and the configuration of Earth materials influencing the hazard (for example, biomass, substrate) (ACSES103)

The cause and impact of global climate change

Natural processes (for example, oceanic circulation, orbitally-induced solar radiation fluctuations, the plate tectonic supercycle) and human activities contribute to global climate changes that are evident at a variety of time scales (ACSES104)

Human activities, particularly land-clearing and fossil fuel consumption, produce gases (including carbon dioxide, methane, nitrous oxide and hydrofluorocarbons) and particulate materials that change the composition of the atmosphere and climatic conditions (for example, the enhanced greenhouse effect) (ACSES105)

Climate change affects the biosphere, atmosphere, geosphere and hydrosphere; climate change has been linked to changes in species distribution, crop productivity, sea level, rainfall patterns, surface temperature and extent of ice sheets (ACSES106)

Geological, prehistorical and historical records provide evidence (for example, fossils, pollen grains, ice core data, isotopic ratios, indigenous art sites) that climate change has affected different regions and species differently over time (ACSES107)

Climate change models (for example, general circulation models, models of El Nino and La Nina) describe the behaviour and interactions of the oceans and atmosphere; these models are developed through the analysis of past and current climate data, with the aim of predicting the response of global climate to changes in the contributing components (for example, changes in global ice cover and atmospheric composition) (ACSES108)

Units 3 and 4 Achievement Standards

Earth and Environmental Science concepts, models and applications

A	B	C	D	E
For the Earth systems studied, the student:	*For the Earth systems studied, the student:*	*For the Earth systems studied, the student:*	*For the Earth systems studied, the student:*	*For the Earth systems studied, the*

Earth and Environmental Science concepts, models and applications

				student:

Earth and Environmental Science concepts, models and applications

• analyses how human activities and Earth processes affect components of, and interactions between, Earth systems across a range of temporal and spatial scales • analyses how interactions between Earth systems change, and how these changes are monitored and managed across a range of temporal and spatial scales • explains the theories and model/s used to explain the systems, the supporting evidence and their limitations and assumptions • applies theories and models of systems and processes to explain phenomena and critically analyse complex problems and make reasoned, plausible predictions in unfamiliar contexts *For the Earth and environmental contexts studied, the student:*	• explains how human activities and Earth processes affect components of, and interactions between, Earth systems • explains how interactions between Earth systems change, and how these changes are monitored and managed • describes the theories and model/s used to explain the systems, some supporting evidence, and their limitations • applies theories and models of systems and processes to explain phenomena, analyse problems and make plausible predictions in unfamiliar contexts *For the Earth and environmental contexts*	• explains how human activities and Earth processes affect components of Earth systems • explains how components of Earth systems change, and how these changes are managed • describes key aspects of a theory or model used to explain system processes and the phenomena to which they can be applied • applies theories or models of systems and processes to explain phenomena, interpret problems and make plausible predictions in some unfamiliar contexts *For the Earth and environmental contexts studied, the student:*	• describes how human activities and Earth processes affect components of Earth systems • describes changes to components of Earth systems and some management responses • describes key aspects of a theory or model used to explain a system process • describes phenomena, interprets simple problems and makes predictions in familiar contexts *For the Earth and environmental contexts studied, the student:* • describes the role of communication	• identifies some human activities and Earth processes that impact components of Earth systems • describes some changes to components of Earth systems, and a related management response • identifies aspects of a theory or model related to a system process • describes phenomena and makes simple predictions in familiar contexts *For the Earth and environmental contexts studied, the student:* • identifies that

Earth and Environmental Science concepts, models and applications

• analyses the role of collaboration, debate and review, and technologies, in the development of Earth and environmental theories and models • evaluates how Earth and environmental science has been used in concert with other sciences to meet diverse needs and inform decision making; and how these applications are influenced by interacting social, economic and ethical factors	*studied, the student:* • explains the role of collaboration, debate and review, and technologies, in the development of Earth and environmental theories and models • explains how Earth and environmental science has been used to meet diverse needs and inform decision making; and how these applications are influenced by social, economic and ethical factors	• describes the role of collaboration and review, and technologies, in the development of Earth and environmental theories or models • discusses how Earth and environmental science has been used to meet needs and inform decision making, and some social, economic or ethical implications of these applications	and new evidence in developing Earth and environmental knowledge • describes ways in which Earth and environmental science has been used in society to meet needs and identifies some implications of these applications	Earth and environmental knowledge has changed over time • identifies ways in which Earth and environmental science has been used in society to meet needs

Earth and Environmental Science inquiry skills

A	B	C	D	E
For the Earth and environmental contexts studied, the student:	*For the Earth and environmental contexts studied, the student:*	*For the Earth and environmental contexts studied, the student:*	*For the Earth and environmental contexts studied, the student:*	*For the Earth and environmental contexts studied, the student:*

Earth and Environmental Science inquiry skills

• designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories and develops evidence-based conclusions that identify limitations • evaluates processes and claims; provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories 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 describe complex relationships and solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies and sources of error • selects data to demonstrate relationships linked to Earth and environmental knowledge and provides conclusions based on data • evaluates processes and claims and suggests improvements or alternatives • selects, constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

Earth and Environmental Science Glossary

Accuracy

The extent to which a measurement result represents the quantity it purports to measure; an accurate measurement result includes an estimate of the true value and an estimate of the uncertainty.

Animal ethics

Animal ethics involves consideration of respectful, fair and just treatment of animals. The use of animals in science involves consideration of replacement (substitution of insentient materials for conscious living animals), reduction (using only the minimum number of animals to satisfy research statistical requirements) and refinement (decrease in the incidence or severity of 'inhumane' procedures applied to those animals that still have to be used).

Biogeochemical cycles

Pathways by which chemical substances move through the biosphere, lithosphere, atmosphere, and hydrosphere.

Biomass

The mass of living matter (microbial, plant and animal) in a given environmental area.

Biomass pyramid

A representation of the total biomass at each trophic level within a system.

Biophysical interactions

Interaction between the biotic and abiotic elements of the atmosphere, hydrosphere, lithosphere and biosphere.

Carrying capacity

The largest number of individuals (within populations) that can be supported by the ecosystem.

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.

Environmental sampling techniques

Techniques used to survey, measure, quantify, assess and monitor biotic and abiotic components of the environment and their interactions; techniques used depend on the subject and purpose of the study and may include: random quadrats, transects, grid arrays, netting, trapping, aerial surveys and rock, soil, air and water sampling.

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.

Field metering equipment

Tools used in the field to measure and record environmental parameters including light meters, weather stations, electromagnetic induction (EMI) meters, magnetometers and radioactivity sensors.

Field work

Observational research undertaken in the normal environment of the subject of the study.

Genre

The categories into which texts are grouped; genre distinguishes texts on the basis of their subject matter, form and structure (for example, scientific reports, field guides, explanations, procedures, biographies, media articles, persuasive texts, narratives).

Hypothesis

A tentative explanation for an observed phenomenon, expressed as a precise and unambiguous statement 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. Investigations can include observation, research, field work, laboratory experimentation and manipulation of simulations.

Law

A statement describing invariable relationships between phenomena in specified conditions, frequently expressed mathematically.

Mapping and field location techniques

Techniques used in the field to describe the field location and to measure and record data and field observations, including use of maps, global positioning system (GPS), magnetic compasses and electronic devices with geopositioning capacity (for example, cameras).

Measurement error

The difference between the measurement result and a currently accepted or standard value of a quantity.

Media texts

Spoken, print, graphic or electronic communications with a public audience. Media texts can be found in newspapers, magazines and on television, film, radio, computer software and the internet.

Mode

The various processes of communication – listening, speaking, reading/viewing and writing/creating.

Model

A representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea.

Population

A group of organisms of one species that interbreed and live in the same place at the same time.

Primary data

Data collected directly by a person or group.

Primary source

Report of data created by the person or persons directly involved in observations of one or more events, experiments, investigations or projects.

Principle of Uniformitarianism

The principle that all geologic phenomena may be explained as the result of existing forces having operated similarly from the origin of Earth to the present time.

Reliability

The degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

Reliable data

Data that has been judged to have a high level of reliability; reliability is the degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

Representation

A verbal, visual, physical or mathematical demonstration of understanding of a science concept or concepts. A concept can be represented in a range of ways and using multiple modes.

Research

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

Research ethics

Norms of conduct that determine ethical research behaviour; research ethics are governed by principles such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics.

Risk assessment

Evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities. Requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate.

Rock and soil sampling and identification procedures

Procedures used in the field to enable rock and soil sampling and identification, including use of classification charts, geological hammer, hand lens, soil auger, soil pH kit and other soil testing chemicals (for example, dilute acid).

Secondary data

Data collected by a person or group other than the person or group using the data.

Secondary source

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

Simulation

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

Spatial analysis

The range of techniques used to examine imagery and datasets covering large spatial areas and commonly compiled in geographical information systems (GIS) including maps, satellite imagery, aerial photographs, geophysical data sets, water or rock samples and other directly sensed data.

Stratigraphy

Study of rock layers and layering of materials such as sediments including ash, meteoritic impact ejecta layers, and soils.

System

A group of interacting objects, materials or processes that form an integrated whole. Systems can be open or closed.

Tectonic plate supercycle

The cycling of Earth over a period of 400 to 600 million years from a single continent and ocean with an inferred icehouse climate to many continents and oceans with a moderate to warm climate.

Theory

A set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena. Theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power.

Uncertainty

Range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment.

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.

The Australian Curriculum
Physics

Physics

Rationale and Aims

Rationale

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

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

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

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

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

Aims

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

Physics

Organisation

Overview of the senior secondary Australian Curriculum

ACARA has developed senior secondary Australian Curriculum for English, Mathematics, Science and History according to a set of design specifications. The ACARA Board approved these specifications following consultation with state and territory curriculum, assessment and certification authorities.

The senior secondary Australian Curriculum specifies 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) expected of 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 and examinations). 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 their courses. They 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 local courses that integrate the Australian Curriculum content and achievement standards and any additional information, guidelines and rules to satisfy local requirements including advice on entry and exit points and credit for completed study.

The senior secondary Australian Curriculum for each subject should not, therefore, be read as a course of study. Rather, it is presented as content and achievement standards for integration into state and territory courses.

Senior secondary Science subjects

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

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

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: Thermal, nuclear and electrical physics
- Unit 2: Linear motion and waves
- Unit 3: Gravity and electromagnetism
- Unit 4: Revolutions in modern physics.

In Units 1 and 2, students further investigate energy, motion and forces, building on the ideas introduced in the F–10 Australian Curriculum: Science. In Unit 1, students investigate energy production by considering heating processes, radioactivity and nuclear reactions, and investigate energy transfer and transformation in electrical circuits. In Unit 2, students 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 them to describe, explain and predict a wider range of phenomena, including, in Unit 4, very high speed motion and very small scale objects. In Unit 3, students investigate models of motion in gravitational, electric and magnetic fields to explain how forces act at a distance, and use 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 of particle physics.

Each unit includes:

- Unit descriptions – short descriptions of the purpose of and rationale for each unit
- Learning outcomes – six to eight statements describing the learning expected as a result of studying the unit
- Content descriptions – descriptions of the core content to be taught and learned, organised into three strands:
  - *Science Inquiry Skills*
  - *Science as a Human Endeavour*
  - *Science Understanding (organised in sub-units).*

Organisation of content

Science strand descriptions

The Australian Curriculum: Science has three interrelated strands: *Science Inquiry Skills, Science as a Human Endeavour* and *Science Understanding*. These strands are used to organise the Science learning area from Foundation to Year 12. In the Senior Secondary Science subjects, the three strands build on students' learning in the F-10 Australian Curriculum: Science.

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. Students' experiences of school science should mirror 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 for *Science Inquiry Skills*, *Science as a Human Endeavour* and *Science Understanding* have been written so that this integration is possible in each unit.

Science Inquiry Skills

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

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

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

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 more specific skills to be taught within the 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:

- Identifying, researching and constructing questions for investigation; proposing hypotheses; and predicting possible outcomes
- Designing investigations, including the procedure/s 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
- Conducting investigations, including using equipment and techniques safely, competently and methodically for the collection of valid and reliable data
- Representing data in meaningful and useful ways; organising and analysing data to identify trends, patterns and relationships; recognising error, uncertainty and limitations in data; and selecting, synthesising and using evidence to construct and justify conclusions
- Interpreting scientific and media texts and evaluating processes, claims and conclusions by considering the quality of available evidence; and using reasoning to construct scientific arguments
- Selecting, constructing and using appropriate representations to communicate understanding, solve problems and make predictions
- Communicating to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes.

The Senior secondary science subjects have been designed to accommodate, if appropriate, an extended scientific investigation within 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.

Science as a Human Endeavour

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

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

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

Across the senior secondary Science subjects, the same set of *Science as a Human Endeavour* content descriptions is used for Units 1 and 2 of the subjects; and another set for Units 3 and 4. This consistent approach enables students to develop a rich appreciation of the complex ways in which science interacts with society, through the exploration of *Science as a Human Endeavour* concepts across the subjects and in multiple contexts.

'Examples in context' will be developed to illustrate possible contexts related to *Science Understanding* content, in which students could explore *Science as a Human Endeavour* concepts. These will be made available to complement the final online curriculum. Each *Example in context* will be aligned to the relevant sub-unit in *Science Understanding* and will include links to the relevant *Science as a Human Endeavour* content descriptions.

Science Understanding

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

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

Science understanding can be developed through the selection of contexts that have relevance to and are engaging for students. The Australian Curriculum: Science has been designed to provide jurisdictions, schools and teachers with the flexibility to select contexts that meet the social, geographic and learning needs of their students.

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 strands of *Science Understanding* and *Science as a Human Endeavour*.

Senior secondary achievement standards have been written for each Australian Curriculum senior secondary subject. The achievement standards provide an indication of typical performance at five different levels (corresponding to grades A to E) following the completion of study of senior secondary Australian Curriculum content for a pair of units. They are broad statements of understanding and skills that are best read and understood in conjunction with the relevant unit content. They are structured to reflect key dimensions of the content of the relevant learning area. They will be eventually accompanied by illustrative and annotated samples of student work/ performance/ responses.

The achievement standards will be refined empirically through an analysis of samples of student work and responses to assessment tasks: they cannot be maintained *a priori* without reference to actual student performance. Inferences can be drawn about the quality of student learning on the basis of observable differences in the extent, complexity, sophistication and generality of the understanding and skills typically demonstrated by students in response to well-designed assessment activities and tasks.

In the short term, achievement standards will inform assessment processes used by curriculum, assessment and certifying authorities for course offerings based on senior secondary Australian Curriculum content.

ACARA has made reference to a common syntax (as a guide, not a rule) in constructing the achievement standards across the learning areas. The common syntax that has guided development is as follows:

- Given a specified context (as described in the curriculum content)
- With a defined level of consistency/accuracy (the assumption that each level describes what the student does well, competently, independently, consistently)
- Students perform a specified action (described through a verb)
- In relation to what is valued in the curriculum (specified as the object or subject)
- With a defined degree of sophistication, difficulty, complexity (described as an indication of quality)

Terms such as 'analyse' and 'describe' have been used to specify particular action but these can have everyday meanings that are quite general. ACARA has therefore associated these terms with specific meanings that are defined in the senior secondary achievement standards glossary and used precisely and consistently across subject areas.

Links to Foundation to Year 10

Progression from the F-10 Australian Curriculum: Science

The Physics curriculum continues 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 arguments, claims or conclusions. In gathering and recording numerical data, students are required to make measurements with an appropriate degree of accuracy and to represent measurements using appropriate units.

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

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

It is assumed that students will be able to competently:

- perform calculations involving addition, subtraction, multiplication and division of quantities
- perform approximate evaluations of numerical expressions
- express fractions as percentages, and percentages as fractions
- calculate percentages
- recognise and use ratios
- transform decimal notation to power of ten notation
- change the subject of a simple equation

- substitute physical quantities into an equation using consistent units so as to calculate one quantity and check the dimensional consistency of such calculations
- solve simple algebraic equations
- comprehend and use the symbols/notations $<$, $>$, Δ, $\approx$, $\surd$, $\leq$, $\geq$, $\sum$
- translate information between graphical, numerical and algebraic forms
- distinguish between discrete and continuous data and then select appropriate forms, variables and scales for constructing graphs
- construct and interpret frequency tables and diagrams, pie charts and histograms
- describe and compare data sets using mean, median and inter-quartile range
- interpret the slope of a linear graph
- calculate areas of right-angled and isosceles triangles, circumference and area of circles, areas and volumes of rectangular blocks, cylinders and spheres
- use Pythagoras' theorem, similarity of triangles and the angle sum of a triangle.

Representation of General capabilities

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

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

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

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

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

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

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

Representation of Cross-curriculum priorities

While the significance of the cross-curriculum priorities for Physics varies, there are opportunities for teachers to select contexts that incorporate the key concepts from each priority.

Through an investigation of contexts that draw on *Aboriginal and Torres Strait Islander histories and cultures* students can appreciate Aboriginal and Torres Strait Islander Peoples' understanding of physical phenomena, including of the motion of objects, and of astronomical phenomena.

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

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 temporal and spatial scales. By investigating the relationships between systems and system components and how systems respond to change, students develop an appreciation for the ways in which matter and energy interactions shape the Earth system. In exploring applications of physics knowledge, students appreciate that science provides the basis for decision making in many areas of society and that these decisions can impact the Earth system. They understand the importance of using physical science knowledge to predict possible effects of human and other activity, and to develop management plans or alternative technologies that minimise these effects and provide for a more sustainable future.

Safety

Science learning experiences may involve the use of potentially hazardous substances and/or hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students and that school practices meet the requirements of the *Work Health and Safety Act 2011,* in addition to relevant state 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.

Animal ethics

Through a consideration of research ethics as part of *Science Inquiry Skills*, students will examine their own ethical position, draw on ethical perspectives when designing investigation methods, and ensure that any activities that impact on living organisms comply with the *Australian code of practice for the care and use of animals for scientific purposes 7th edition* (2004) (http://www.nhmrc.gov.au/guidelines/publications/ea16) .

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*, in addition to relevant state or territory guidelines.

When state and territory curriculum authorities integrate the Australian Curriculum into local courses, they will include more specific advice on the care and use of, or interaction with, animals.

For further information about relevant guidelines or to access your local Animal Ethics Committee, contact your state or territory curriculum authority.

Unit 1: Thermal, nuclear and electrical physics

Unit Description

An understanding of heating processes, nuclear reactions and electricity is essential to appreciate how global energy needs are met. In this unit, students explore the ways physics is used to describe, explain and predict the energy transfers and transformations that are pivotal to modern industrial societies. Students investigate heating processes, apply the nuclear model of the atom to investigate radioactivity, and learn how nuclear reactions convert mass into energy. They examine the movement of electrical charge in circuits and use this to analyse, explain and predict electrical phenomena.

Contexts that could be investigated in this unit include technologies related to nuclear, thermal, or geothermal energy, electrical energy production, large-scale power systems, radiopharmaceuticals and electricity in the home; and related areas of science such as nuclear fusion in stars and the Big Bang theory.

Through the investigation of appropriate contexts, students understand how applying scientific knowledge to the challenge of meeting world energy needs requires the international cooperation of multidisciplinary teams and relies on advances in ICT and other technologies. They explore how science knowledge is used to offer valid explanations and reliable predictions, and the ways in which it interacts with social, economic, cultural and ethical factors.

Students develop skills in interpreting, constructing and using 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 heat transfer, heat capacity, 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 charge is involved in the transfer and transformation of energy in electrical circuits
- understand how scientific models and theories have developed and are applied to improve existing, and develop new, technologies
- 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
- use algebraic and graphical representations to calculate, analyse and predict measurable quantities associated with heating processes, nuclear reactions and electrical circuits
- evaluate, with reference to empirical evidence, claims about heating processes, nuclear reactions and electrical technologies
- communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills

Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSPH001)

Design investigations, including the procedure/s 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 (ACSPH002)

Conduct investigations, including using temperature, current and potential difference measuring devices, safely, competently and methodically for the collection of valid and reliable data (ACSPH003)

Represent data in meaningful and useful ways, including using appropriate Système Internationale (SI) units and symbols; organise and analyse data to identify trends, patterns and relationships; identify sources of random and systematic error and estimate their effect on measurement results; identify anomalous data and calculate the measurement discrepancy between experimental results and a currently accepted value, expressed as a percentage; and select, synthesise and use evidence to make and justify conclusions (ACSPH004)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSPH005)

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 (ACSPH006)

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 (ACSPH007)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSPH008)

Science as a Human Endeavour (Units 1 & 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSPH009)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSPH010)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSPH011)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSPH012)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSPH013)

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSPH014)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSPH015)

Science Understanding

Heating processes

Heat transfer occurs between and within systems by conduction, convection and/or radiation (ACSPH016)

The kinetic particle model describes matter as consisting of particles in constant motion, except at absolute zero (ACSPH017)

All systems have thermal energy due to the motion of particles in the system (ACSPH018)

Temperature is a measure of the average kinetic energy of particles in a system (ACSPH019)

Provided a substance does not change state, its temperature change is proportional to the amount of energy added to or removed from the substance; the constant of proportionality describes the heat capacity of the substance (ACSPH020)

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 (ACSPH021)

Two systems in contact transfer energy between particles so that eventually the systems reach the same temperature; that is, they are in thermal equilibrium (ACSPH022)

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 (ACSPH023)

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 (ACSPH024)

Energy transfers and transformations in mechanical systems (for example, internal and external combustion engines, electric motors) always result in some heat loss to the environment, so that the usable energy is reduced and the system cannot be 100 percent efficient (ACSPH025)

Mathematical representations and relationships

$\mathrm{Q} = \mathrm{mc}\Delta\mathrm{T}$

$\mathrm{Q} =$ heat transferred to or from the object, $\mathrm{m} =$ mass of object, $\mathrm{c} =$ specific heat capacity of the object, $\Delta\mathrm{T} =$ temperature change

$\mathrm{Q} = \mathrm{mL}$

$\mathrm{Q} =$ heat transferred to or from the object, L = latent heat capacity of the material, $\mathrm{m} =$ mass of object

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

$\eta =$ efficiency

Ionising radiation and nuclear reactions

The nuclear model of the atom describes the atom as consisting of an extremely small nucleus, which contains most of the atom's mass and is made up of positively charged protons and uncharged neutrons surrounded by negatively charged electrons (ACSPH026)

Nuclear stability is the result of the strong nuclear force, which operates between nucleons over a very short distance and opposes the electrostatic repulsion between protons in the nucleus (ACSPH027)

Some nuclides are unstable and spontaneously decay, emitting alpha, beta and/or gamma radiation over time until they become stable nuclides (ACSPH028)

Each species of radionuclide has a specific half-life (ACSPH029)

Alpha, beta and gamma radiation have sufficient energy to ionise atoms (ACSPH030)

Einstein's mass/energy relationship, which applies to all energy changes, enables the energy released in nuclear reactions to be determined from the mass change in the reaction (ACSPH031)

Alpha and beta decay are examples of spontaneous transmutation reactions, while artificial transmutation is a managed process that changes one nuclide into another (ACSPH032)

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 (ACSPH033)

A fission chain reaction is a self-sustaining process that may be controlled to produce thermal energy, or uncontrolled to release energy explosively (ACSPH034)

Nuclear fusion is a reaction in which light nuclides combine to form a heavier nuclide, with the release of energy (ACSPH035)

More energy is released per nucleon in nuclear fusion than in nuclear fission because a greater percentage of the mass is transformed into energy (ACSPH036)

Mathematical representations and relationships

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

$\mathrm{N} =$ number of nuclides remaining in a sample, $\mathbf{n}$ = number of whole half-lives, $\mathrm{N_o} =$ original number of nuclides in the sample

$\Delta\mathrm{E} = \Delta\mathrm{mc}^2$

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

Electrical circuits

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 and kinetic energy, and light. (ACSPH037)

Electric current is carried by discrete charge carriers; charge is conserved at all points in an electrical circuit (ACSPH038)

Energy is conserved in the energy transfers and transformations that occur in an electrical circuit (ACSPH039)

The energy available to charges moving in an electrical 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 (ACSPH040)

Energy is required to separate positive and negative charge carriers; charge separation produces an electrical potential difference that can be used to drive current in circuits (ACSPH041)

Power is the rate at which energy is transformed by a circuit component; power enables quantitative analysis of energy transformations in the circuit (ACSPH042)

Resistance for ohmic and non-ohmic components is defined as the ratio of potential difference across the component to the current in the component (ACSPH043)

Circuit analysis and design involve calculation of the potential difference across, the current in, and the power supplied to, components in series, parallel and series/parallel circuits (ACSPH044)

Mathematical representations and relationships

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

$I =$ current, $q =$ the amount of charge that passes a point in the circuit, $t =$ time interval

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

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

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

R = resistance, V = potential difference, $I =$ current

For ohmic resistors, resistance, R, is a constant

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

$P =$ power, W = work = energy transformed, t = 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 = 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

Physics

Unit 2: Linear Motion and Waves

Unit Description

In this unit, students develop an appreciation of how an understanding of motion and waves can be used to describe, explain and predict a wide range of phenomena. Students describe linear motion in terms of position and time data, and examine the relationships between force, momentum and energy for interactions in one dimension.

Students investigate common 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.

Contexts that could be investigated in this unit include technologies such as accelerometers, motion-detectors, photo radar, GPS, energy conversion buoys, music, hearing aids, echo locators, fibre optics, DVDs and lasers, and related areas of science and engineering such as sports science, car and road safety, acoustic design, noise pollution, seismology, bridge and building design.

Through the investigation of appropriate contexts, students explore how international collaboration, evidence from a range of disciplines and many individuals, and the development of ICT and other technologies have contributed to developing understanding of motion and waves and associated technologies. They investigate how scientific knowledge is used to offer valid explanations and reliable predictions, and the ways in which it interacts with social, economic, cultural and ethical factors.

Students develop their understanding of motion and wave phenomena through laboratory 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 Newton’s Laws of Motion describe the relationship between the forces acting on an object and its motion
- understand that waves transfer energy and that a wave model can be used to explain the behaviour of sound and light
- understand how scientific models and theories have developed and are applied to improve existing, and develop new, technologies
- use science inquiry skills to design, conduct and analyse safe and effective investigations into linear motion and wave phenomena, and to communicate methods and findings
- use algebraic and graphical representations to calculate, analyse and predict measurable quantities associated with linear and wave motion
- evaluate, with reference to evidence, claims about motion, sound and light-related phenomena and associated technologies
- communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSPH045)

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 (ACSPH046)

Conduct investigations, including the manipulation of devices to measure motion and the direction of light rays, safely, competently and methodically for the collection of valid and reliable data (ACSPH047)

Represent data in meaningful and useful ways, including using appropriate SI units and symbols; organise and analyse data to identify trends, patterns and relationships; identify sources of random and systematic error and estimate their effect on measurement results; identify anomalous data and calculate the measurement discrepancy between the experimental results and a currently accepted value, expressed as a percentage; and select, synthesise and use evidence to make and justify conclusions (ACSPH048)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSPH049)

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 (ACSPH050)

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 (ACSPH051)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSPH052)

Science as a Human Endeavour (Units 1 & 2)

Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility (ACSPH053)

Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines (ACSPH054)

Advances in science understanding in one field can influence other areas of science, technology and engineering (ACSPH055)

The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations (ACSPH056)

The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences (ACSPH057)

Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions (ACSPH058)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSPH059)

Science Understanding

Linear motion and force

Uniformly accelerated motion is described in terms of relationships between measurable scalar and vector quantities, including displacement, speed, velocity and acceleration (ACSPH060)

Representations, including graphs and vectors, and/or equations of motion, can be used qualitatively and quantitatively to describe and predict linear motion (ACSPH061)

Vertical motion is analysed by assuming the acceleration due to gravity is constant near Earth's surface (ACSPH062)

Newton's Three Laws of Motion describe the relationship between the force or forces acting on an object, modelled as a point mass, and the motion of the object due to the application of the force or forces (ACSPH063)

Momentum is a property of moving objects; it is conserved in a closed system and may be transferred from one object to another when a force acts over a time interval (ACSPH064)

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 potential energy of objects (ACSPH065)

Collisions may be elastic and inelastic; kinetic energy is conserved in elastic collisions (ACSPH066)

Mathematical representations and relationships

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

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

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

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

$W = \Delta E;$ where the applied force is in the same direction as the displacement, $W = Fs,$

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

$p = mv$, $\Delta p = F\Delta t$

p = momentum, $v =$ velocity, $m =$ mass, F = force, $p =$change in momentum,

Δt = time interval over which force F acts

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

$E_k =$ kinetic energy, $m =$ mass, $v =$ speed

$\Delta E_p = mg\Delta h$

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

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

$\Sigma mv_{before} =$ vector sum of the momenta of all particles before the collision, $\Sigma mv_{after} =$ vector sum of the momenta of all particles after the collision

For elastic collisions: $\Sigma \frac{1}{2} mv^2_{before} = \Sigma \frac{1}{2} mv^2_{after}$

$\Sigma \frac{1}{2} mv^2_{before} =$ sum of the kinetic energies before the collision, $\Sigma \frac{1}{2} mv^2_{after} =$ sum of the kinetic energies after the collision

Waves

Waves are periodic oscillations that transfer energy from one point to another (ACSPH067)

Longitudinal and transverse waves are distinguished by the relationship between the direction of oscillation relative to the direction of the wave velocity (ACSPH068)

Waves may be represented by time and displacement wave diagrams and described in terms of relationships between measurable quantities, including period, amplitude, wavelength, frequency and velocity (ACSPH069)

Mechanical waves transfer energy through a medium; mechanical waves may oscillate the medium or oscillate the pressure within the medium (ACSPH070)

The mechanical wave model can be used to explain phenomena related to reflection and refraction (for example, echoes, seismic phenomena) (ACSPH071)

The superposition of waves in a medium may lead to the formation of standing waves and interference phenomena, including standing waves in pipes and on stretched strings (ACSPH072)

A mechanical system resonates when it is driven at one of its natural frequencies of oscillation; energy is transferred efficiently into systems under these conditions (ACSPH073)

Light exhibits many wave properties; however, it cannot be modelled as a mechanical wave because it can travel through a vacuum (ACSPH074)

A ray model of light may be used to describe reflection, refraction and image formation from lenses and mirrors (ACSPH075)

A wave model explains a wide range of light-related phenomena including reflection, refraction, total internal reflection, dispersion, diffraction and interference; a transverse wave model is required to explain polarisation (ACSPH076)

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 a point source (ACSPH077)

Mathematical representations and relationships

$\mathrm{v} = \mathrm{f}\lambda$

$\mathrm{v} =$ speed, $\mathrm{f} =$ frequency, $\lambda =$ wavelength

angle of incidence = angle of reflection

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

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

$\mathrm{n} =$ whole numbers 1, 2, 3… relating to the harmonic, $\mathrm{l} =$ length of string or pipe, $\lambda =$ wavelength of sound wave

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

$\mathrm{I} =$ intensity, $\mathrm{r} =$ distance from the source

$\frac{\sin \mathrm{i}}{\sin \mathrm{r}} = \frac{\mathrm{v}_1}{\mathrm{v}_2} = \frac{\lambda_1}{\lambda_2}$

$\mathrm{i} =$ incident angle (relative to the normal), $\mathrm{r} =$ angle of refraction (relative to the normal), $\mathrm{v}_1 =$ velocity in medium 1, $\mathrm{v}_2 =$ velocity in medium 2, $\lambda_1 =$ wavelength in medium 1, λ_2 = wavelength in medium 2

Units 1 and 2 Achievement Standards

Physics concepts, models and applications

A	B	C	D	E
For the physical systems studied, the student:	*For the physical systems studied, the student*:	*For the physical systems studied, the student:*	*For the physical systems studied, the*	*For the physical systems studied,*

Physics concepts, models and applications

			student:	the student:
• analyses physical phenomena in complex scenarios qualitatively and quantitatively • analyses the relationships between components and properties of physical systems qualitatively and quantitatively • explains the theories and model/s used to explain the system and the aspects of the system they include • applies theories and models of systems and processes to explain phenomena, interpret complex problems, and make reasoned, plausible predictions in unfamiliar contexts *For the physical science contexts studied, the student:* • analyses the roles of collaboration, debate and review, and technologies, in the development of physical science theories and models • evaluates how physical science has been used in concert with other sciences to meet diverse needs and to inform decision making, and how these applications are influenced by interacting social, economic and ethical factors	• explains physical phenomena qualitatively and quantitatively • explains the relationships between components and properties of physical systems qualitatively and quantitatively • describes the theories and model/s used to explain the system • applies theories and models of systems and processes to explain phenomena, interpret problems, and make plausible predictions in unfamiliar contexts *For the physical science contexts studied, the student:* • explains the roles of collaboration, debate and review, and technologies, in the development of physical science theories and models • explains how physical science has been used to meet diverse needs and to inform decision making, and how these applications are influenced by social, economic and ethical factors	• describes physical phenomena in simple scenarios qualitatively and quantitatively • describes the relationships between components and properties of physical systems qualitatively • describes a theory or model used to explain the system • applies theories or models of systems and processes to explain phenomena, interpret problems, and make plausible predictions in familiar contexts *For the physical science contexts studied, the student:* • describes the roles of collaboration, review, and technologies, in the development of physical science theories or models • discusses how physical science has been used to meet needs and to inform decision making, and discusses some social, economic or ethical implications of these applications	• describes physical phenomena in simple scenarios qualitatively • describes how components of physical systems are related • identifies aspects of a theory or model related to the system • describes phenomena, interprets simple problems, and makes simple predictions in familiar contexts *For the physical science contexts studied, the student:* • describes the roles of communication and new evidence in developing physical science knowledge • describes ways in which physical science has been used in society to meet needs, and identifies some implications of these applications	• Identifies properties of physical phenomena • identifies components of physical systems • identifies aspects of a theory or model related to parts of the system • describes phenomena and makes simple predictions in familiar, simple contexts *For the physical science contexts studied, the student:* • identifies that physical science knowledge has changed over time • identifies ways in which physical science has been used in society to meet needs

Physics inquiry skills

A	B	C	D	E
For the physical science contexts studied, the student:	*For the physical science contexts studied, the*	*For the physical science contexts studied, the*	*For the physical science contexts*	*For the physical science contexts*

Physics inquiry skills

	student:	*student:*	*studied, the student:*	*studied, the student:*

Physics inquiry skills

Physics inquiry skills

• designs, conducts				

Physics inquiry skills

designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories, and develops evidence-based conclusions that identify limitations • evaluates processes and claims, and provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies, and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories, 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 describe complex relationships and solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies, and sources of error • selects data to demonstrate relationships linked to physical science knowledge, and provides conclusions based on data • evaluates processes and claims, and suggests improvements or alternatives • selects, constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends, and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

Unit 3: Gravity and electromagnetism

Unit Description

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

Contexts that could be investigated in this unit include technologies such as artificial satellites, navigation devices, large-scale electrical power generation and distribution, motors and generators, electric cars, synchrotron science, medical imaging and astronomical telescopes such as the Square Kilometre Array, and related areas of science and engineering such as sports science, amusement parks, ballistics, forensics, black holes and dark matter.

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

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

Learning Outcomes

By the end of this unit, students:

- understand that motion in gravitational, electric and magnetic fields can be explained using Newton's Laws of Motion
- understand how the electromagnetic wave model explains the production and propagation of electromagnetic waves across the electromagnetic spectrum
- understand transformations and transfer of energy in electromagnetic devices, as well as transformations and transfer of energy associated with motion in electric, magnetic and gravitational fields
- understand how models and theories have developed over time, and the ways in which physical science knowledge and associated technologies interact with social, economic, cultural and ethical considerations
- use science inquiry skills to design, conduct, analyse and evaluate investigations into uniform circular motion, projectile motion, satellite motion and gravitational and electromagnetic phenomena, and to communicate methods and findings
- use algebraic and graphical representations to calculate, analyse and predict measurable quantities related to motion, gravitational effects and electromagnetic phenomena
- evaluate, with reference to evidence, claims about motion, gravity and electromagnetic phenomena and associated technologies, and justify evaluations
- communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSPH078)

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 (ACSPH079)

Conduct investigations, including the manipulation of force measurers and electromagnetic devices, safely, competently and methodically for the collection of valid and reliable data (ACSPH080)

Represent data in meaningful and useful ways, including using appropriate SI units, symbols and significant figures; organise and analyse data to identify trends, patterns and relationships; identify sources of uncertainty and techniques to minimise these uncertainties; utilise uncertainty and percentage uncertainty to determine the uncertainty in the result of calculations, and evaluate the impact of measurement uncertainty on experimental results; and select, synthesise and use evidence to make and justify conclusions (ACSPH081)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the accuracy and precision of available evidence; and use reasoning to construct scientific arguments (ACSPH082)

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 (ACSPH083)

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 (ACSPH084)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSPH085)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of datasets with which scientists work (ACSPH086)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSPH087)

The acceptance of science understanding can be influenced by the social, economic and cultural context in which it is considered (ACSPH088)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSPH089)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSPH090)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSPH091)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSPH092)

Science Understanding

Gravity and motion

The movement of free-falling bodies in Earth's gravitational field is predictable (ACSPH093)

All objects with mass attract one another with a gravitational force; the magnitude of this force can be calculated using Newton's Law of Universal Gravitation (ACSPH094)

Objects with mass produce a gravitational field in the space that surrounds them; field theory attributes the gravitational force on an object to the presence of a gravitational field (ACSPH095)

When a mass moves or is moved from one point to another in a gravitational field and its potential energy changes, work is done on or by the field (ACSPH096)

Gravitational field strength is defined as the net force per unit mass at a particular point in the field (ACSPH097)

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 (ACSPH098)

Projectile motion can be analysed quantitatively by treating the horizontal and vertical components of the motion independently (ACSPH099)

When an object experiences a net force of constant magnitude perpendicular to its velocity, it will undergo uniform circular motion, including circular motion on a horizontal plane and around a banked track (ACSPH100)

Newton's Law of Universal Gravitation is used to explain Kepler's laws of planetary motion and to describe the motion of planets and other satellites, modelled as uniform circular motion (ACSPH101)

Mathematical representations and relationships

$\mathrm{w} = \mathrm{mg}$

$\mathrm{w}\ =$ weight force, $\mathrm{m}\ =$ mass, $\mathrm{g}\ =$ acceleration due to gravity (gravitational field strength)

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

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

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

$\mathrm{y}\ =$ vertical displacement, x = horizontal displacement, $\mathrm{u_y}\ =$ initial vertical velocity, $\mathrm{v_y}\ =$ vertical velocity at time t, $\mathrm{u_x}\ =$ initial horizontal velocity, $\mathrm{v_x}\ =$ horizontal velocity at time t, $\mathrm{g}\ =$ speed of light acceleration due to gravity, $\mathrm{t}\ =$ time into flight

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

$\mathrm{v} =$ tangential velocity, T = period

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

$\mathrm{a_c}\ =$ centripetal acceleration, $\mathrm{v}\ =$ tangential velocity, $\mathrm{r}\ =$ radius of the circle

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

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

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

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

Electromagnetism

Electrostatically charged objects exert a force upon one another; the magnitude of this force can be calculated using Coulomb's Law (ACSPH102)

Point charges and charged objects produce an electric field in the space that surrounds them; field theory attributes the electrostatic force on a point charge or charged body to the presence of an electric field (ACSPH103)

A positively charged body placed in an electric field will experience a force in the direction of the field; the strength of the electric field is defined as the force per unit charge (ACSPH104)

When a charged body moves or is moved from one point to another in an electric field and its potential energy changes, work is done on or by the field (ACSPH105)

Current-carrying wires are surrounded by magnetic fields; these fields are utilised in solenoids and electromagnets

(ACSPH106)

The strength of the magnetic field produced by a current is called the magnetic flux density (ACSPH107)

Magnets, magnetic materials, moving charges and current-carrying wires experience a force in a magnetic field; this force is utilised in DC electric motors (ACSPH108)

Magnetic flux is defined in terms of magnetic flux density and area (ACSPH109)

A changing magnetic flux induces a potential difference; this process of electromagnetic induction is used in step-up and step-down transformers, DC and AC generators, and AC induction motors (ACSPH110)

Conservation of energy, expressed as Lenz's Law of electromagnetic induction, is used to determine the direction of induced current (ACSPH111)

Electromagnetic waves are transverse waves made up of mutually perpendicular, oscillating electric and magnetic fields (ACSPH112)

Oscillating charges produce electromagnetic waves of the same frequency as the oscillation; electromagnetic waves cause charges to oscillate at the frequency of the wave (ACSPH113)

Mathematical representations and relationships

$\mathrm{F} = \frac{1}{4\pi\varepsilon_0}\frac{\mathrm{Qq}}{\mathrm{r}^2}$

$\mathrm{F} =$ force, $\frac{1}{4\pi\varepsilon_o} =$ Coulomb constant $\left(9 \times 10^9 \mathrm{~N~m^2~C^{-2}}\right)$, $\mathrm{q} =$ charge on the first object, $\mathrm{Q} =$ charge on the second object, $\mathrm{r} =$ separation between the charges

$\mathrm{E} = \frac{\mathrm{F}}{\mathrm{q}} = \frac{1}{4\pi\varepsilon_0}\frac{\mathrm{q}}{\mathrm{r}^2}$

$\mathrm{E} =$ electric field strength, $\mathrm{F} =$ force, $\mathrm{q} =$ charge, $\mathrm{r} =$ distance from the charge, $\frac{1}{4\pi\varepsilon_o} =$ Coulomb constant $\left(9 \times 10^9 \mathrm{~N~m^2~C^{-2}}\right)$

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

$\mathrm{V} =$ electrical potential difference, $\Delta\mathrm{U} =$ change in potential energy, $\mathrm{q} =$ charge

$\mathrm{B} = \frac{\mu_o\mathrm{I}}{2\pi\mathrm{r}}$

$\mathrm{B} =$ magnetic flux density, $\mathrm{I} =$ current in wire, $\mathrm{r} =$ distance from the centre of the wire, $\frac{\mu_o}{2\pi} =$ magnetic constant $(2 \times 10^{-7}\mathrm{T~A^{-1}m})$

For a straight, current carrying wire perpendicular to a magnetic field $\mathrm{F} = \mathrm{BIl}$

$\mathrm{B} =$ magnetic flux density, $\mathrm{F} =$ force on the wire, $\mathrm{l} =$length of wire in the magnetic field, I = current in the wire

For a charge moving perpendicular to a magnetic field $\mathrm{F} = \mathrm{qvB}$

$\mathrm{F} =$ force on a charge moving in an applied magnetic field, $\mathrm{q} =$ charge, $\mathrm{v} =$ velocity of the charge, $\mathrm{B} =$ magnetic flux density

$\phi = \mathrm{BA}_\perp$

$\phi =$ magnetic flux, $\mathrm{A}_\perp =$ area of current loop perpendicular to the applied magnetic field, $\mathrm{B} =$ magnetic flux density

$\mathrm{emf} = -\frac{\mathrm{n}\triangle\left(\mathrm{BA}_\perp\right)}{\Delta\mathrm{t}} = -\mathrm{n}\frac{\Delta\phi}{\Delta\mathrm{t}}$

$\mathrm{emf} =$ induced potential difference, $\phi =$ change in magnetic flux, $\mathrm{n} =$ number of windings in the loop, $\mathrm{A}_\perp =$ area of current loop perpendicular to the applied magnetic field, $\Delta\mathrm{t} =$ time interval over which the magnetic flux change occurs, $\mathrm{B} =$ magnetic flux density

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

$\mathrm{V_p} =$ potential difference across the primary coil, $\mathrm{V_s} =$ potential difference across the secondary coil, $\mathrm{n_p} =$ number of turns on primary coil, $\mathrm{n_s} =$ number of turns on secondary coil

$\mathrm{I_p V_p} = \mathrm{I_s V_s}$

$\mathrm{I_p} =$ current in primary coil, $\mathrm{V_p} =$ potential difference across primary coil, $\mathrm{I_s}$ = current in secondary coil, $\mathrm{V_s}$ = potential difference across secondary coil

Physics

Unit 4: Revolutions in modern physics

Unit Description

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

Contexts that could be investigated in this unit include technologies such as GPS navigation, lasers, modern electric lighting, medical imaging, nanotechnology, semiconductors, quantum computers and particle accelerators; and related areas of science such as space travel, the digital revolution and the greenhouse effect.

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

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

Learning Outcomes

By the end of this unit, students:

- understand the consequences for space and time of the equivalence principle for inertial frames of reference
- understand how the quantum theory of light and matter explains blackbody radiation, the photoelectric effect, and atomic emission and absorption spectra
- understand how the Standard Model explains the nature of and interaction between the fundamental particles that form the building blocks of matter
- understand how models and theories have developed over time, and the ways in which physical science knowledge and associated technologies interact with social, economic, cultural and ethical considerations
- use science inquiry skills to design, conduct, analyse and evaluate investigations into frames of reference, diffraction, black body and atomic emission spectra, the photoelectric effect, and photonic devices, and to communicate methods and findings
- use algebraic and graphical models to solve problems and make predictions related to the theory and applications of special relativity, quantum theory and the Standard Model
- evaluate the experimental evidence that supports the theory of relativity, wave-particle duality, the Bohr model of the atom, the Standard Model, and the Big Bang theory
- communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.

Content Descriptions

Science Inquiry Skills

Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes (ACSPH114)

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 (ACSPH115)

Conduct investigations, including use of simulations and manipulation of spectral devices, safely, competently and methodically for the collection of valid and reliable data (ACSPH116)

Represent data in meaningful and useful ways, including using appropriate SI units, symbols and significant figures; organise and analyse data to identify trends, patterns and relationships; identify sources of uncertainty and techniques to minimise these uncertainties; utilise uncertainty and percentage uncertainty to determine the cumulative uncertainty resulting from calculations, and evaluate the impact of measurement uncertainty on experimental results; and select, synthesise and use evidence to make and justify conclusions (ACSPH117)

Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSPH118)

Select, construct and use appropriate representations, including text and graphic representations of empirical and theoretical relationships, simulations, simple reaction diagrams and atomic energy level diagrams, to communicate conceptual understanding, solve problems and make predictions (ACSPH119)

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 (ACSPH120)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSPH121)

Science as a Human Endeavour (Units 3 & 4)

ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of datasets with which scientists work (ACSPH122)

Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power (ACSPH123)

The acceptance of science understanding can be influenced by the social, economic and cultural context in which it is considered (ACSPH124)

People can use scientific knowledge to inform the monitoring, assessment and evaluation of risk (ACSPH125)

Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question (ACSPH126)

International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia-Pacific region (ACSPH127)

Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability (ACSPH128)

Science Understanding

Special relativity

Observations of objects travelling at very high speeds cannot be explained by Newtonian physics (for example, the dilated half-life of high-speed muons created in the upper atmosphere, and the momentum of high speed particles in particle accelerators) (ACSPH129)

Einstein's special theory of relativity predicts significantly different results to those of Newtonian physics for velocities approaching the speed of light (ACSPH130)

The special theory of relativity is based on two postulates: that the speed of light in a vacuum is an absolute constant, and that all inertial reference frames are equivalent (ACSPH131)

Motion can only be measured relative to an observer; length and time are relative quantities that depend on the observer's frame of reference (ACSPH132)

Relativistic momentum increases at high relative speed and prevents an object from reaching the speed of light (ACSPH133)

The concept of mass-energy equivalence emerged from the special theory of relativity and explains the source of the energy produced in nuclear reactions (ACSPH134)

Mathematical representations and relationships

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

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 $\left(3 \times 10^8 \text{ m s}^{-1}\right)$

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

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 $\left(3 \times 10^8 \text{ m s}^{-1}\right)$

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

p_v = relativistic momentum for an object moving with velocity, v, with respect to the observer, m = mass, c = speed of light $\left(3 \times 10^8 \text{ m s}^{-1}\right)$

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

ΔE = change in energy, Δm = change in mass, c = speed of light $\left(3 \times 10^8 \text{ m s}^{-1}\right)$

Quantum theory

Atomic phenomena and the interaction of light with matter indicate that states of matter and energy are quantised into discrete values (ACSPH135)

On the atomic level, electromagnetic radiation is emitted or absorbed in discrete packets called photons; the energy of a photon is proportional to its frequency; and the constant of proportionality, Planck's constant, can be determined experimentally (for example, from the photoelectric effect or the threshold voltage of coloured LEDs) (ACSPH136)

A wide range of phenomena, including black body radiation and the photoelectric effect, are explained using the concept of light quanta (ACSPH137)

Atoms of an element emit and absorb specific wavelengths of light that are unique to that element; this is the basis of spectral analysis (ACSPH138)

The Bohr model of the hydrogen atom integrates light quanta and atomic energy states to explain the specific wavelengths in the hydrogen spectrum and in the spectra of other simple atoms; the Bohr model enables line spectra to be correlated with atomic energy-level diagrams (ACSPH139)

On the atomic level, energy and matter exhibit the characteristics of both waves and particles (for example, Young's double slit experiment is explained with a wave model but produces the same interference pattern when one photon at a time is passed through the slits) (ACSPH140)

Mathematical representations and relationships

$\mathrm{E} = \mathrm{hf}$

E = energy of photon, f = frequency, h = Planck's constant $\left(6.626 \times 10^{-34}\ \mathrm{J\ s}\right)$

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

$\lambda_{\mathrm{max}} =$ peak wavelength , $\mathrm{T} =$ absolute temperature, b = Wien's displacement constant $(2.898 \times 10^{-3}\ \mathrm{m\ K})$

$\mathrm{E_k} = \mathrm{hf} - \mathrm{W}$

$\mathrm{E_k} =$ kinetic energy of photoelectron, hf = energy of incident photon, $\mathrm{W} =$ work function of the material

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

$\lambda =$ wavelength associated with particle, p = momentum of particle, h = Planck's constant $\left(6.626 \times 10^{-34}\ \mathrm{J\ s}\right)$

$\mathrm{n}\lambda = 2\pi\mathrm{r}$

n = an integer 1, 2, 3, 4... , $\lambda =$ wavelength of electron, r = orbital radius of electron

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

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 $\left(6.626 \times 10^{-34}\ \mathrm{J\ s}\right)$

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

$\lambda =$ wavelength of spectral line, $\mathrm{n_i} =$ principal quantum number of initial electron state, $\mathrm{n_f} =$ principal quantum number of final electron state, R = Rydberg's constant $(1.097 \times 10^{7}\ \mathrm{m^{-1}})$

The Standard Model

The Standard Model is based on the premise that all matter in the universe is made up from elementary matter particles called quarks and leptons; quarks experience the strong force, leptons do not (ACSPH141)

The Standard Model explains three of the four fundamental forces (strong, weak and electromagnetic forces) in terms of an exchange of force-carrying particles called gauge bosons; each force is mediated by a different type of gauge boson (ACSPH142)

Reactions between particles can be represented by simple reaction diagrams (ACSPH143)

Lepton number and baryon number are examples of quantities that are conserved in all reactions between particles; conservation laws can be used to support or invalidate proposed reactions (ACSPH144)

Variations of reactions can be found by applying symmetry operations to known reactions. These include reversing the direction of the reaction diagram (time reversal symmetry) and replacing all particles with their antiparticles and vice versa (charge reversal symmetry). Energy and momentum must also be conserved for such a reaction to be possible. (ACSPH145)

High-energy particle accelerators are used to test theories of particle physics including the Standard Model (ACSPH146)

The Standard Model is used to describe the evolution of forces and the creation of matter in the Big Bang theory (ACSPH147)

Units 3 and 4 Achievement Standards

Physics concepts, models and applications

A	B	C	D	E
For the physical systems studied, the student:	*For the physical systems studied, the student:*	*For the physical systems studied, the student:*	*For the physical systems studied, the*	*For the physical systems studied,*

Physics concepts, models and applications

			student:	*the student:*

Physics concepts, models and applications

• analyses physical phenomena in complex scenarios at a range of scales qualitatively and quantitatively • analyses the relationships between mass, energy and properties of physical systems qualitatively and quantitatively • explains the theories and model/s used to explain the system, the supporting evidence, and their limitations and assumptions • applies theories and models of systems and processes to explain phenomena, critically analyse complex problems, and make reasoned, plausible predictions in unfamiliar contexts *For the physical science contexts studied, the student:*	• explains physical phenomena at a range of scales qualitatively and quantitatively • explains the relationships between mass, energy and properties of physical systems qualitatively and quantitatively • describes the theories and model/s used to explain the system, some supporting evidence, and their limitations • applies theories and models of systems and processes to explain phenomena, analyse problems, and make plausible	• explains physical phenomena qualitatively and quantitatively • explains the relationships between mass, energy and properties of physical systems qualitatively • describes key aspects of a theory or model used to explain system processes, and the phenomena to which they can be applied • applies theories or models of systems and processes to explain phenomena, interpret problems, and	• describes physical phenomena qualitatively • describes how components and properties of physical systems are related • describes key aspects of a theory or model used to explain a system process • describes phenomena, interprets simple problems, and makes predictions in familiar contexts *For the physical science contexts studied, the student:*	• describes properties of physical phenomena • describes components of physical systems • identifies aspects of a theory or model related to a system process • describes phenomena and makes simple predictions in familiar contexts *For the physical science contexts studied, the student:* • identifies that physical

Physics concepts, models and applications

• analyses the roles of collaboration, debate and review, and technologies, in the development of physical science theories and models • evaluates how physical science has been used in concert with other sciences to meet diverse needs and to inform decision making; and how these applications are influenced by interacting social, economic and ethical factors	predictions in unfamiliar contexts *For the physical science contexts studied, the student:* • explains the roles of collaboration, debate and review, and technologies, in the development of physical science theories and models • explains how physical science has been used to meet diverse needs and to inform decision making; and how these applications are influenced by social, economic and ethical factors	make plausible predictions in some unfamiliar contexts *For the physical science contexts studied, the student:* • describes the roles of collaboration and review, and technologies, in the development of physical science theories or models • discusses how physical science has been used to meet needs and to inform decision making, and some social, economic or ethical implications of these applications	• describes the roles of communication and new evidence in developing physical science knowledge • describes ways in which physical science has been used in society to meet needs, and identifies some implications of these applications	science knowledge has changed over time • identifies ways in which physical science has been used in society to meet needs

Physics inquiry skills

A	B	C	D	E
For the physical science contexts studied, the student:	*For the physical science contexts studied, the*	*For the physical science contexts studied, the*	*For the physical science contexts*	*For the physical science contexts*

Physics inquiry skills

	student:	*student:*	*studied, the student:*	*studied, the student:*

Physics inquiry skills

Physics inquiry skills

• designs, conducts				

Physics inquiry skills

designs, conducts and improves safe, ethical investigations that efficiently collect valid, reliable data in response to a complex question or problem • analyses data sets to explain causal and correlational relationships, the reliability of the data, and sources of error • justifies their selection of data as evidence, analyses evidence with reference to models and/or theories, and develops evidence-based conclusions that identify limitations • evaluates processes and claims, and provides an evidence-based critique and discussion of improvements or alternatives • selects, constructs and uses appropriate representations to describe complex relationships and solve complex and unfamiliar problems • communicates effectively and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs, conducts and improves safe, ethical investigations that collect valid, reliable data in response to a question or problem • analyses data sets to identify causal and correlational relationships, anomalies, and sources of error • selects appropriate data as evidence, interprets evidence with reference to models and/or theories, 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 describe complex relationships and solve unfamiliar problems • communicates clearly and accurately in a range of modes, styles and genres for specific audiences and purposes	• designs and conducts safe, ethical investigations that collect valid data in response to a question or problem • analyses data to identify relationships, anomalies, and sources of error • selects data to demonstrate relationships linked to physical science knowledge, and provides conclusions based on data • evaluates processes and claims, and suggests improvements or alternatives • selects, constructs and uses appropriate representations to describe relationships and solve problems • communicates clearly in a range of modes, styles and genres for specific purposes	• plans and conducts safe, ethical investigations to collect data in response to a question or problem • analyses data to identify trends and anomalies • selects data to demonstrate trends, and presents simple conclusions based on data • considers processes and claims from a personal perspective • constructs and uses simple representations to describe relationships and solve simple problems • communicates in a range of modes and genres	• follows a procedure to conduct safe, ethical investigations to collect data • identifies trends in data • selects data to demonstrate trends • considers claims from a personal perspective • constructs and uses simple representations to describe phenomena • communicates in a range of modes

Physics Glossary

Absolute uncertainty

Estimate of the dispersion of the measurement result; the range of values around the measurement result that is most likely to include the true value.

Accuracy

The extent to which a measurement result represents the quantity it purports to measure; an accurate measurement result includes an estimate of the true value and an estimate of the uncertainty.

Algebraic representation

A set of symbols linked by mathematical operations; the set of symbols summarise relationships between variables.

Animal ethics

Animal ethics involves consideration of respectful, fair and just treatment of animals. The use of animals in science involves consideration of replacement (substitution of insentient materials for conscious living animals), reduction (using only the minimum number of animals to satisfy research statistical requirements) and refinement (decrease in the incidence or severity of 'inhumane' procedures applied to those animals that still have to be used).

Anomalous data

Data that does not fit a pattern; outlier.

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.

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.

Fundamental forces

Four fundamental forces have been identified. They are, in order from strongest to weakest, the strong, electromagnetic, weak and gravity forces.

Genre

The categories into which texts are grouped; genre distinguishes texts on the basis of their subject matter, form and structure (for example, scientific reports, field guides, explanations, procedures, biographies, media articles, persuasive texts, narratives).

Hypothesis

A tentative explanation for an observed phenomenon, expressed as a precise and unambiguous statement 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. Investigations can include observation, research, field work, laboratory experimentation and manipulation of simulations.

Law

A statement describing invariable relationships between phenomena in specified conditions, frequently expressed mathematically.

Measurement discrepancy

The difference between the measurement result and a currently accepted or standard value of a quantity.

Media texts

Spoken, print, graphic or electronic communications with a public audience. Media texts can be found in newspapers, magazines and on television, film, radio, computer software and the internet.

Mode

The various processes of communication – listening, speaking, reading/viewing and writing/creating.

Model

A representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea.

Primary data

Data collected directly by a person or group.

Primary source

Report of data created by the person or persons directly involved in observations of one or more events, experiments, investigations or projects.

Random error

Uncontrollable effects of the measurement equipment, procedure and environment on a measurement result; the magnitude of random error for a measurement result can be estimated by finding the spread of values around the average of independent, repeated measurements of the quantity.

Reliability

The degree to which an assessment instrument or protocol consistently and repeatedly measures an attribute achieving similar results for the same population.

Reliable data

Data that have 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.

Representation

A verbal, visual, physical or mathematical demonstration of understanding of a science concept or concepts. A concept can be represented in a range of ways and using multiple modes.

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

Research ethics
Norms of conduct that determine ethical research behaviour; research ethics are governed by principles such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics.

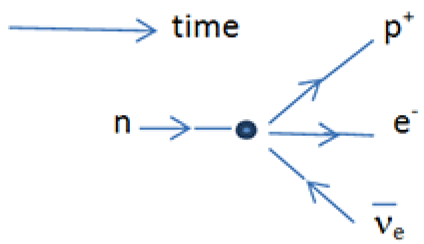
Risk assessment
Evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities. Requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate.

Secondary data
Data collected by a person or group other than the person or group using the data.

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

Significant figures
The use of place value to represent a measurement result accurately and precisely.

Simple reaction diagrams
A visual representation of reactions between subatomic particles. In the diagram, time runs from left to right. The lines represent particles and the circle represents the reaction process. Antiparticles have the time arrow reversed.



Simulation
A representation of a process, event or system which imitates a real or idealised situation.

System
A group of interacting objects, materials or processes that form an integrated whole. Systems can be open or closed.

Systematic error
The contribution to the uncertainty in a measurement result that is identifiable and quantifiable, for example, imperfect calibration of measurement instruments.

Theory

A set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena. Theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power.

Uncertainty

Range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment.

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.

Glossary

Abstract

Abstract scenario: a scenario for which there is no concrete referent provided.

Account

Account for: provide reasons for (something).

Give an account of: report or describe an event or experience.

Taking into account: considering other information or aspects.

Analyse

Consider in detail for the purpose of finding meaning or relationships, and identifying patterns, similarities and differences.

Apply

Use, utilise or employ in a particular situation.

Assess

Determine the value, significance or extent of (something).

Coherent

Orderly, logical, and internally consistent relation of parts.

Communicates

Conveys knowledge and/or understandings to others.

Compare

Estimate, measure or note how things are similar or dissimilar.

Complex

Consisting of multiple interconnected parts or factors.

Considered

Formed after careful thought.

Critically analyse

Examine the component parts of an issue or information, for example the premise of an argument and its plausibility, illogical reasoning or faulty conclusions

Critically evaluate

Evaluation of an issue or information that includes considering important factors and available evidence in making critical judgement that can be justified.

Deduce

Arrive at a conclusion by reasoning.

Demonstrate
Give a practical exhibition as an explanation.

Describe
Give an account of characteristics or features.

Design
Plan and evaluate the construction of a product or process.

Develop
In history: to construct, elaborate or expand.

In English: begin to build an opinion or idea.

Discuss
Talk or write about a topic, taking into account different issues and ideas.

Distinguish
Recognise point/s of difference.

Evaluate
Provide a detailed examination and substantiated judgement concerning the merit, significance or value of something.

In mathematics: calculate the value of a function at a particular value of its independent variables.

Explain
Provide additional information that demonstrates understanding of reasoning and/or application.

Familiar
Previously encountered in prior learning activities.

Identify
Establish or indicate who or what someone or something is.

Integrate
Combine elements.

Investigate
Plan, collect and interpret data/information and draw conclusions about.

Justify
Show how an argument or conclusion is right or reasonable.

Locate
Identify where something is found.

Manipulate
Adapt or change.

Non-routine

Non-routine problems: Problems solved using procedures not previously encountered in prior learning activities.

Reasonableness

Reasonableness of conclusions or judgements: the extent to which a conclusion or judgement is sound and makes sense

Reasoned

Reasoned argument/conclusion: one that is sound, well-grounded, considered and thought out.

Recognise

Be aware of or acknowledge.

Relate

Tell or report about happenings, events or circumstances.

Represent

Use words, images, symbols or signs to convey meaning.

Reproduce

Copy or make close imitation.

Responding

In English: When students listen to, read or view texts they interact with those texts to make meaning. Responding involves students identifying, selecting, describing, comprehending, imagining, interpreting, analysing and evaluating.

Routine problems

Routine problems: Problems solved using procedures encountered in prior learning activities.

Select

Choose in preference to another or others.

Sequence

Arrange in order.

Solve

Work out a correct solution to a problem.

Structured

Arranged in a given organised sequence.

In Mathematics: When students provide a structured solution, the solution follows an organised sequence provided by a third party.

Substantiate

Establish proof using evidence.

Succinct

Written briefly and clearly expressed.

Sustained

Consistency maintained throughout.

Synthesise

Combine elements (information/ideas/components) into a coherent whole.

Understand

Perceive what is meant, grasp an idea, and to be thoroughly familiar with.

Unfamiliar

Not previously encountered in prior learning activities.