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CONTENTS

Introduction	1
Subject description	1
Capabilities	2
Aboriginal and Torres Strait Islander knowledge, cultures, and perspectives	4
Health and safety	4
Learning scope and requirements	5
Learning requirements	5
Content	5
Assessment scope and requirements	54
Evidence of learning	54
Assessment design criteria	54
School assessment	55
External assessment	59
Performance standards	59
Assessment integrity	61
Support materials	62
Subject-specific advice	62
Advice on ethical study and research	62

INTRODUCTION

SUBJECT DESCRIPTION

Physics is a 10-credit subject or a 20-credit subject at Stage 1 and a 20-credit subject at Stage 2.

The study of Physics is constructed around using qualitative and quantitative models, laws, and theories to better understand matter, forces, energy, and the interaction among them. Physics seeks to explain natural phenomena, from the subatomic world to the macrocosmos, and to make predictions about them. The models, laws, and theories in physics are based on evidence obtained from observations, measurements, and active experimentation over thousands of years.

By studying physics, students understand how new evidence can lead to the refinement of existing models and theories and to the development of different, more complex ideas, technologies, and innovations.

Through further developing skills in gathering, analysing, and interpreting primary and secondary data to investigate a range of phenomena and technologies, students increase their understanding of physics concepts and the impact that physics has on many aspects of contemporary life.

By exploring science as a human endeavour, students develop and apply their understanding of the complex ways in which science interacts with society, and investigate the dynamic nature of physics. They explore how physicists develop new understanding and insights, and produce innovative solutions to everyday and complex problems and challenges in local, national, and global contexts.

In Physics, students integrate and apply a range of understanding, inquiry, and scientific thinking skills that encourage and inspire them to contribute their own solutions to current and future problems and challenges. Students also pursue scientific pathways, for example, in engineering, renewable energy generation, communications, materials innovation, transport and vehicle safety, medical science, scientific research, and the exploration of the universe.

CAPABILITIES

The capabilities connect student learning within and across subjects in a range of contexts. They include essential knowledge and skills that enable people to act in effective and successful ways.

The SACE identifies seven capabilities. They are:

- literacy
- numeracy
- information and communication technology (ICT) capability
- critical and creative thinking
- personal and social capability
- ethical understanding
- intercultural understanding.

Literacy

In this subject students extend and apply their literacy capability by, for example:

- interpreting the work of scientists across disciplines using physics knowledge
- critically analysing and evaluating primary and secondary data
- extracting physics information presented in a variety of modes
- using a range of communication formats to express ideas logically and fluently, incorporating the terminology and conventions of physics
- synthesising evidence-based arguments
- communicating appropriately for specific purposes and audiences.

Numeracy

In this subject students extend and apply their numeracy capability by, for example:

- solving problems using calculations and critical thinking skills
- measuring with appropriate instruments
- recording, collating, representing, and analysing primary data
- accessing and interpreting secondary data
- identifying and interpreting trends and relationships
- calculating and predicting values by manipulating data and using appropriate scientific conventions.

Information and communication technology (ICT) capability

In this subject students extend and apply their ICT capability by, for example:

- locating and accessing information
- collecting, analysing, and representing data electronically
- modelling concepts and relationships
- using technologies to create new ways of thinking about science

- communicating physics ideas, processes, and information
- understanding the impact of ICT on the development of physics and its application in society
- evaluating the application of ICT to advance understanding and investigations in physics.

Critical and creative thinking

In this subject students extend and apply critical and creative thinking by, for example:

- analysing and interpreting problems from different perspectives
- deconstructing a problem to determine the most appropriate method for investigation
- constructing, reviewing, and revising hypotheses to design investigations
- interpreting and evaluating data and procedures to develop logical conclusions
- analysing interpretations and claims, for validity and reliability
- devising imaginative solutions and making reasonable predictions
- envisaging consequences and speculating on possible outcomes
- recognising the significance of creative thinking on the development of physics knowledge and applications.

Personal and social capability

In this subject students extend and apply their personal and social capability by, for example:

- understanding the importance of physics knowledge on health and well-being, both personally and globally
- making decisions and taking initiative while working independently and collaboratively
- planning effectively, managing time, following procedures effectively, and working safely
- sharing and discussing ideas about physics issues, developments, and innovations while respecting the perspectives of others
- recognising the role of their own beliefs and attitudes in gauging the impact of physics in society
- seeking, valuing, and acting on feedback.

Ethical understanding

In this subject students extend and apply their ethical understanding by, for example:

- considering the implications of their investigations on organisms and the environment
- making ethical decisions based on an understanding of physics principles
- using data and reporting the outcomes of investigations accurately and fairly
- acknowledging the need to plan for the future and to protect and sustain the biosphere
- recognising the importance of their responsible participation in social, political, economic, and legal decision-making.

Intercultural understanding

In this subject students extend and apply their intercultural understanding by, for example:

- recognising that science is a global endeavour with significant contributions from diverse cultures
- respecting and engaging with different cultural views and customs and exploring their interaction with scientific research and practices
- being open-minded and receptive to change in the light of scientific thinking based on new information
- understanding that the progress of physics influences and is influenced by cultural factors.

ABORIGINAL AND TORRES STRAIT ISLANDER KNOWLEDGE, CULTURES, AND PERSPECTIVES

In partnership with Aboriginal and Torres Strait Islander communities, and schools and school sectors, the SACE Board of South Australia supports the development of high-quality learning and assessment design that respects the diverse knowledge, cultures, and perspectives of Indigenous Australians.

The SACE Board encourages teachers to include Aboriginal and Torres Strait Islander knowledge and perspectives in the design, delivery, and assessment of teaching and learning programs by:

- providing opportunities in SACE subjects for students to learn about Aboriginal and Torres Strait Islander histories, cultures, and contemporary experiences
- recognising and respecting the significant contribution of Aboriginal and Torres Strait Islander peoples to Australian society
- drawing students' attention to the value of Aboriginal and Torres Strait Islander knowledge and perspectives from the past and the present
- promoting the use of culturally appropriate protocols when engaging with and learning from Aboriginal and Torres Strait Islander peoples and communities.

HEALTH AND SAFETY

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 2012*, in addition to relevant state, territory, or national health and safety guidelines. Information about these procedures is available from the school sectors.

The following safety practices must be observed in all laboratory work:

- Use equipment only under the direction and supervision of a teacher or other qualified person.
- Follow safety procedures when preparing or manipulating apparatus.
- Use appropriate safety gear when preparing or manipulating apparatus.

Particular care must be taken when using electrical apparatus, ionising and non-ionising radiation, and lasers, but care must not be limited to these items.

LEARNING SCOPE AND REQUIREMENTS

LEARNING REQUIREMENTS

The learning requirements summarise the knowledge, skills, and understanding that students are expected to develop and demonstrate through their learning in Stage 2 Physics.

In this subject, students are expected to:

1. apply science inquiry skills to deconstruct a problem and design and conduct physics investigations, using appropriate procedures and safe, ethical working practices
2. obtain, record, represent, analyse, and interpret the results of physics investigations
3. evaluate procedures and results, and analyse evidence to formulate and justify conclusions
4. develop and apply knowledge and understanding of physics concepts in new and familiar contexts
5. explore and understand science as a human endeavour
6. communicate knowledge and understanding of physics concepts, using appropriate terms, conventions, and representations.

CONTENT

Stage 2 Physics is a 20-credit subject.

The topics in Stage 2 Physics provide the framework for developing integrated programs of learning through which students extend their skills, knowledge, and understanding of the three strands of science.

The three strands of science to be integrated throughout student learning are:

- science inquiry skills
- science as a human endeavour
- science understanding.

The topics for Stage 2 Physics are:

- Topic 1: Motion and relativity
- Topic 2: Electricity and magnetism
- Topic 3: Light and atoms.

Students study all three topics. The topics can be sequenced and structured to suit individual groups of students.

The following pages describe in more detail:

- science inquiry skills
- science as a human endeavour
- the topics for science understanding.

The descriptions of the science inquiry skills and the topics are structured in two columns: the left-hand column sets out the science inquiry skills or science understanding and the right-hand column sets out possible contexts.

Together with science as a human endeavour, the science inquiry skills and science understanding form the basis of teaching, learning, and assessment in this subject.

The possible contexts are suggestions for potential inquiry approaches, and are neither comprehensive nor exclusive. Teachers may select from these and are encouraged to consider other inquiry approaches according to local needs and interests.

Within the topic descriptions, the following symbols are used in the possible contexts to show how a strand of science can be integrated:



indicates a possible teaching and learning strategy for science understanding



indicates a possible science inquiry activity



indicates a possible focus on science as a human endeavour.

Science Inquiry Skills

In Physics, investigation is an integral part of the learning and understanding of concepts, by using scientific methods to test ideas and develop new knowledge.

Practical investigations must involve a range of both individual and collaborative activities, during which students extend the science inquiry skills described in the table that follows.

Practical activities may take a range of forms, such as developing and using models and simulations that enable students to develop a better understanding of particular concepts. The activities include laboratory and field studies during which students develop investigable questions and/or testable hypotheses, and select and use equipment appropriately to collect data. The data may be observations, measurements, or other information obtained during the investigation. Students represent and analyse the data they have collected; evaluate procedures, and describe the limitations of the data and procedures; consider explanations for their observations; and present and justify conclusions appropriate to the initial question or hypothesis.

It is recommended that a minimum of 16–20 hours of class time involves practical activities.

Science inquiry skills are fundamental to students investigating the social, ethical, and environmental impacts and influences of the development of scientific understanding and the applications, possibilities, and limitations of science. These skills enable students to critically analyse the evidence they obtain so that they can present and justify a conclusion.

Science Inquiry Skills	Possible contexts
<p>Scientific methods enable systematic investigation to obtain measurable evidence.</p> <ul style="list-style-type: none"> Deconstruct a problem to determine and justify the most appropriate method for investigation. Design investigations, including: <ul style="list-style-type: none"> hypothesis or inquiry question types of variables <ul style="list-style-type: none"> dependent independent factors held constant (how and why they are controlled) factors that may not be able to be controlled (and why not) materials required the method to be followed the type and amount of data to be collected identification of ethical and safety considerations. 	<p>Develop inquiry skills by, for example:</p> <ul style="list-style-type: none"> designing investigations that require investigable questions and imaginative solutions (with or without implementation) critiquing proposed investigations using the conclusion of one investigation to propose subsequent experiments changing an independent variable in a given procedure and adapting the method researching, developing, and trialling a method improving an existing procedure identifying options for measuring the dependent variable researching hazards related to the use and disposal of physics materials developing safety audits identifying relevant ethical and/or legal considerations in different contexts.

Science Inquiry Skills	Possible contexts
<p>Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices.</p> <ul style="list-style-type: none"> Conduct investigations, including: <ul style="list-style-type: none"> selection and safe use of appropriate materials, apparatus, and equipment collection of appropriate primary or secondary data (numerical, visual, descriptive) individual and collaborative work. 	<p>Develop inquiry skills by, for example:</p> <ul style="list-style-type: none"> identifying equipment, materials, or instruments fit for purpose practising techniques and safe use of apparatus comparing resolution of different measuring tools distinguishing between and using primary and secondary data.
<p>Results of investigations are represented in a well-organised way to allow them to be interpreted.</p> <ul style="list-style-type: none"> Represent results of investigations in appropriate ways, including <ul style="list-style-type: none"> use of appropriate SI units, symbols construction of appropriately labelled tables drawing of graphs, including lines or curves of best fit as appropriate use of significant figures. 	<p>Develop inquiry skills by, for example:</p> <ul style="list-style-type: none"> practising constructing tables to tabulate data, including column and row labels with units identifying the appropriate representations to graph different data sets selecting axes and scales, and graphing data clarifying understanding of significant figures using, for example: http://www.astro.yale.edu/astro120/SigFig.pdf https://www.hccfl.edu/media/43516/sigfigs.pdf https://www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm comparing data from different sources to describe as quantitative, qualitative.
<p>Scientific information can be presented using different types of symbols and representations.</p> <ul style="list-style-type: none"> Select, use, and interpret appropriate representations, including: <ul style="list-style-type: none"> mathematical relationships, including direct or inverse proportion and exponential relationships diagrams and multi-image representations formulae <p>to explain concepts, solve problems, and make predictions.</p>	<p>Develop inquiry skills by, for example:</p> <ul style="list-style-type: none"> writing formulae using formulae; deriving and rearranging formulae using proportionality arguments to explore changes to quantities constructing vector diagrams drawing and labelling diagrams sketching field diagrams recording images constructing flow diagrams.

Science Inquiry Skills	Possible contexts
<p>Analysis of the results of investigations allows them to be interpreted in a meaningful way.</p> <ul style="list-style-type: none"> Analyse data, including: <ul style="list-style-type: none"> multi-image representations identification and discussion of trends, patterns, and relationships interpolation or extrapolation where appropriate. 	<p>Develop inquiry skills by, for example:</p> <ul style="list-style-type: none"> analysing data sets to identify trends and patterns determining relationships between independent and dependent variables, including mathematical relationships (e.g. slope, linear, inverse relationships where relevant). discussing inverse and direct proportionality using graphs from different sources (e.g. CSIRO or the Australian Bureau of Statistics (ABS)), to predict values other than plotted points calculating means, standard deviations, percent error, where appropriate.
<p>Critical evaluation of procedures and data can determine the meaningfulness of the results.</p> <ul style="list-style-type: none"> Identify sources of uncertainty, including: <ul style="list-style-type: none"> random and systematic errors uncontrolled factors. Evaluate reliability, accuracy, and validity of results, by discussing factors including: <ul style="list-style-type: none"> sample size precision resolution of equipment random error systematic error factors that cannot be controlled. 	<p>Develop inquiry skills by, for example:</p> <ul style="list-style-type: none"> discussing how the repeating of an investigation with different materials/equipment may detect a systematic error using an example of an investigation report to develop report-writing skills. <p>Useful websites:</p> <p>http://www.nuffieldfoundation.org/practical-physics/designing-and-evaluating-experiments</p> <p>https://physics.appstate.edu/undergraduate-programs/laboratory/resources/error-analysis</p> <p>http://www.physics.gatech.edu/~em92/Lab/physlab/admin1/labpractice.html</p>
<p>Conclusions can be formulated that relate to the hypothesis or inquiry question.</p> <ul style="list-style-type: none"> Select and use evidence and scientific understanding to make and justify conclusions. Recognise the limitations of conclusions. Recognise that the results of some investigations may not lead to definitive conclusions. 	<p>Develop inquiry skills by, for example:</p> <ul style="list-style-type: none"> evaluating procedures and data sets provided by the teacher to determine and hence comment on the limitations of possible conclusions using data sets to discuss the limitations of the data in relation to the range of possible conclusions that could be made.

Science Inquiry Skills	Possible contexts
<p>Effective scientific communication is clear and concise.</p> <ul style="list-style-type: none">• Communicate to specific audiences and for specific purposes using:<ul style="list-style-type: none">♦ appropriate language♦ terminology♦ conventions.	<p>Develop inquiry skills by, for example:</p> <ul style="list-style-type: none">• reviewing scientific articles or presentations to recognise conventions• developing skills in referencing and/or footnoting• distinguishing between reference lists and bibliographies• practising scientific communication in written, oral, and multimodal formats (e.g. presenting a podcast or writing a blog).



Science as a Human Endeavour

The science as a human endeavour strand highlights science as a way of knowing and doing, and explores the purpose, use, and influence of science in society.

By exploring science as a human endeavour, students develop and apply their understanding of the complex ways in which science interacts with society, and investigate the dynamic nature of physics. They explore how physicists develop new understanding and insights, and produce innovative solutions to everyday and complex problems and challenges in local, national, and global contexts. In this way, students are encouraged to think scientifically and make connections between the work of others and their own learning. This enables them to explore their own solutions to current and future problems and challenges.

Students understand that the development of science concepts, models, and theories is a dynamic process that involves analysis of evidence and sometimes produces ambiguity and uncertainty. They consider how and why science concepts, models, and theories are continually reviewed and reassessed as new evidence is obtained and as emerging technologies enable new avenues of investigation. They understand that scientific advancement involves a diverse range of individual scientists and teams of scientists working within an increasingly global community of practice.

Students explore how scientific progress and discoveries are influenced and shaped by a wide range of social, economic, ethical, and cultural factors. They investigate ways in which the application of science may provide great benefits to individuals, the community, and the environment, but may also pose risks and have unexpected outcomes. They understand how decision-making about socio-scientific issues often involves consideration of multiple lines of evidence and a range of needs and values. As critical thinkers, they appreciate science as an ever-evolving body of knowledge that frequently informs public debate, but is not always able to provide definitive answers.

The key concepts of science as a human endeavour underpin the contexts, approaches, and activities in this subject, and must be integrated into all teaching and learning programs.

The key concepts of science as a human endeavour, with elaborations that are neither comprehensive nor exclusive, in the study of Physics are:

Communication and Collaboration

- Science is a global enterprise that relies on clear communication, international conventions, and review and verification of results.
- Collaboration between scientists, governments, and other agencies is often required in scientific research and enterprise.

Development

- Development of complex scientific models and/or theories often requires a wide range of evidence from many sources and across disciplines.
- New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes.

Influence

- Advances in scientific understanding in one field can influence and be influenced by other areas of science, technology, engineering, and mathematics.
- The acceptance and use of scientific knowledge can be influenced by social, economic, cultural, and ethical considerations.

Application and Limitation

- Scientific knowledge, understanding, and inquiry can enable scientists to develop solutions, make discoveries, design action for sustainability, evaluate economic, social, cultural, and environmental impacts, offer valid explanations, and make reliable predictions.
- The use of scientific knowledge may have beneficial or unexpected consequences; this requires monitoring, assessment, and evaluation of risk, and provides opportunities for innovation.
- Science informs public debate and is in turn influenced by public debate; at times, there may be complex, unanticipated variables or insufficient data that may limit possible conclusions.

Topic 1: Motion and relativity

This topic builds upon the concepts of forces and energy developed in Stage 1 Physics. There is a particular focus on the relationships between force and acceleration in different contexts. Students investigate the effect of the acceleration due to gravity on the motion of projectiles using the vector nature of gravitational force. They describe, explain, and interpret projectile motion using qualitative and quantitative methods. Newton's Laws of Motion are used to introduce the vector nature of momentum. This enhances the students' numeracy capability.

The conservation of momentum is used to identify subatomic particles — particles that support the Standard Model covered in Stage 2, Topic 3: Light and atoms. Centripetal acceleration is introduced and Newton's Law of Universal Gravitation is used to explain the nature of the acceleration due to gravity and extend the concept of centripetal acceleration to contemporary applications such as satellites. Centripetal acceleration also has strong connections to the motion of particles in cyclotrons covered in Stage 2, Topic 2: Electricity and magnetism. Newton's Law of Universal Gravitation is also used to explain Kepler's Laws of Planetary Motion: the laws that govern the motion of satellites, comets, planets, and star systems.

The fundamental concepts of classical physics serve as an entry point to modern physics, in particular, the Theory of Special Relativity, formulated by Einstein. Students investigate the relationship between matter and energy at high speeds, and explore the experiments, both from Einstein's time and more recently, that confirm the postulates of special relativity.



Subtopic 1.1: Projectile motion


Students are introduced to the theories and quantitative methods used to describe, determine, and explain projectile motion, both in the absence of air resistance and in media with resistive forces.

Students study projectile motion, through a range of investigations to understand how the principles are applied in the contexts of sports, vehicle designs, and terminal speed.

Science Understanding	Possible contexts
<p>When the acceleration is constant, motion is described in terms of relationships between measurable scalar and vector quantities, including displacement, speed, velocity, and acceleration.</p> <p>Motion under constant acceleration can be described quantitatively using the following formulae:</p> $\vec{v} = \vec{v}_0 + \vec{a}t,$ $\vec{s} = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2 \text{ and}$ $v^2 = v_0^2 + 2as.$ <p>Projectile motion can be analysed quantitatively by treating the horizontal and vertical components of the motion independently.</p> <ul style="list-style-type: none"> Construct, identify, and label displacement, velocity, and acceleration vectors. Resolve velocity into vertical and horizontal components, using $v_H = v \cos \theta$ and $v_V = v \sin \theta$ for the horizontal and vertical components respectively. Solve problems using the constant acceleration formulae. Use vector addition and trigonometric calculations to determine the magnitude and direction of the velocity of a projectile at any moment of time. 	<p><i>Explanation of the difference between scalar and vector quantities and methods of measurement of these quantities is covered in Stage 1, Topic 1: Linear motion and forces.</i></p> <p><i>This uses the concept of acceleration developed in Stage 1, Subtopic 1.1: Motion under constant acceleration.</i></p> <p>Use trigonometric calculations and scale diagrams to determine quantities, using vector addition and subtraction.</p> <p>Given a diagram showing the path of a projectile, draw vectors to show the forces acting on the projectile, as well as the acceleration and velocity vectors.</p> <p>Use a projectile launcher to investigate the effect of launch angle or launch height on range.</p>






Science Understanding	Possible contexts	
<p>An object experiences a constant gravitational force near the surface of the Earth, which causes it to undergo uniform acceleration.</p> <ul style="list-style-type: none"> Explain that, in the absence of air resistance, the horizontal component of the velocity is constant. 		
Science Understanding	Possible contexts	
<p>The motion formulae are used to calculate measurable quantities for objects undergoing projectile motion.</p> <ul style="list-style-type: none"> Calculate the time of flight when a projectile is launched horizontally. Calculate the time of flight and the maximum height for a projectile when the launch height is the same as the landing height. Calculate the horizontal range of a projectile when it is launched horizontally or when the launch height is the same as the landing height (or the flight time is given). Determine the velocity of a projectile at any time using trigonometric calculations or vector addition. Explain qualitatively that the maximum range occurs at a launch angle of 45° for projectiles that land at the same height from which they were launched. Describe the relationship between launch angles that result in the same range. Describe and explain the effect of launch height, speed, and angle on the time of flight, maximum height, and the maximum range of a projectile. Analyse multi-image representations of projectile paths. 	<p>Investigate the 'monkey and the hunter' problem both quantitatively and qualitatively.</p> <p>Use video footage to analyse projectile motion in a variety of contexts.</p> <p>Analyse the constant horizontal component of the velocity of the projectile qualitatively and quantitatively, using various recording technologies.</p> <p>Model and demonstrate that the maximum range occurs at a launch angle other than 45° when the launch height is different to the landing height.</p> <p>In terms of projectile motion, analyse footage of students undertaking a sport like shot put.</p> <p>Use concepts from projectile motion to analyse sporting activities such as aerial skiing, golf, javelin, shot put, and various ball sports.</p>	

Science Understanding	Possible contexts	
<p>When a body moves through a medium (such as air) the body experiences a drag force that opposes the motion of the body.</p> <ul style="list-style-type: none"> • Explain the effects of speed, cross-sectional area of the body, and density of the medium on the drag force on a moving body. • Explain that terminal velocity occurs when the magnitude of the drag force results in zero net force on the moving body. • Describe situations (such as skydiving and the maximum speed of racing cars) where terminal velocity is achieved. • Describe and explain the effects of air resistance on the vertical and horizontal components of the velocity, maximum height, and range of a projectile. • Describe and explain the effects of air resistance on the time for a projectile to reach the maximum height or to fall from the maximum height. 	<p>Determine the terminal velocity of a spherical object by dropping it into a viscous liquid.</p> <p>Determine the drag coefficients by dropping coffee filters or cupcake holders. By manipulating the mass and recording the time taken to reach the ground, use the air resistance formula to calculate the drag coefficient.</p> <p>Discuss the conclusions of experiments comparing swimming in syrup with swimming in water: http://www.nature.com/news/2004/040920/full/news040920-2.html</p>	
	<p>Explore examples of the way that scientists have been able to develop solutions affecting aerodynamics (such as shape, texture, and spin) of different objects like balls, planes, and cars.</p>	

Subtopic 1.2: Forces and momentum

Students learn to use force and acceleration vectors to discuss Newton's Laws of Motion and are introduced to the vector nature of momentum. They explain the law of the conservation of momentum in terms of Newton's Laws and develop skills in vector addition and subtraction within this context.

Science Understanding	Possible contexts	
<p>Momentum is a property of moving objects and is defined as the product of the mass and the velocity of the object. It is conserved in an isolated system and may be transferred from one object to other objects when a force acts over a time interval.</p> <p>Kinetic energy is a property of moving objects, and is given by the formula $E_K = \frac{1}{2}mv^2$</p> <p>Newton's Second Law of Motion can be expressed as two formulae, $\vec{F} = m\vec{a}$ and $\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$, where $\vec{p} = m\vec{v}$ is the momentum of the object.</p> <ul style="list-style-type: none"> Derive $\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$ by substituting the defining formula for acceleration $\left(\vec{a} = \frac{\Delta\vec{v}}{\Delta t}\right)$ into Newton's Second Law of Motion, $\vec{F} = m\vec{a}$, for particles of fixed mass. (The net force, \vec{F}, and hence the acceleration, \vec{a}, are assumed to be constant. Otherwise, average or instantaneous quantities apply.) Draw vector diagrams in one dimension or in two dimensions (with right-angled or equilateral triangles) in which the initial momentum is subtracted from the final momentum, giving the change in momentum, $\Delta\vec{p}$. Solve problems (in both one dimension and two dimensions) using the formulae $\vec{F} = m\vec{a}$, $\vec{p} = m\vec{v}$, $\vec{F} = \frac{\Delta\vec{p}}{\Delta t}$, and $E_K = \frac{1}{2}mv^2$. 	<p>Many of these ideas have been introduced in Stage 1 through one-dimensional situations. The focus here should be on two-dimensional situations.</p> <p>Consider the development of the discovery of neutrinos.</p> <p>This uses the concepts of acceleration and force developed in Stage 1, Subtopics 1.1: Motion under constant acceleration and 1.2: Forces.</p>	
	<p>Use the conservation of momentum to determine the speed of a projectile by firing it into a trolley.</p>	
	<p>Investigate how the law of conservation of momentum was used to predict the existence of neutrinos.</p> <p>Explore perspectives in the public debate about the economics of space exploration. Is government funding likely to be maintained?</p> <p>Research the most appropriate types of spacecraft propulsion for journeys to different destinations, considering technical challenges and speculative technologies.</p>	


Science Understanding	Possible contexts	
<p>Newton's Third Law of Motion states, $\vec{F}_1 = -\vec{F}_2$.</p> <p>Momentum is conserved in an isolated system of particles. In such a system, the particles are subject only to the forces that they exert on each other.</p> <ul style="list-style-type: none"> Derive a formula expressing the conservation of momentum for two interacting particles by substituting $\vec{F}_1 = \frac{\Delta \vec{p}_1}{\Delta t}$ and $\vec{F}_2 = \frac{\Delta \vec{p}_2}{\Delta t}$ into $\vec{F}_1 = -\vec{F}_2$. Use the law of conservation of momentum to solve problems in one and two dimensions. Use vector addition or subtraction in one dimension or in two dimensions (with right-angled or equilateral triangles) to solve problems using the law of conservation of momentum. Analyse multi-image representations to solve conservation of momentum problems, using only situations in which the mass of one object is an integral multiple of the mass of the other object(s). The scale of the representations and the flash rate can be ignored. <p>The conservation of momentum can be used to explain the propulsion of spacecraft, ion thrusters, and solar sails.</p> <ul style="list-style-type: none"> Use the conservation of momentum to describe and explain the change in momentum and acceleration of spacecraft due to the emission of gas particles or ionised particles. Use the conservation of momentum to describe and explain how the reflection of particles of light (photons) can be used to accelerate a solar sail. Use vector diagrams to compare the acceleration of a spacecraft, using a solar sail where photons are reflected with the acceleration of a spacecraft, and using a solar sail where photons are absorbed. 		




Subtopic 1.3: Circular motion and gravitation


Students investigate the circular motion that results from centripetal acceleration in a variety of contexts, including satellites and banked curves. Students are introduced to the concepts of Newton's Law of Universal Gravitation and Kepler's Laws of Planetary Motion.

They explore extraterrestrial phenomena that can be explained using Newton's Law of Universal Gravitation and Kepler's Laws of Planetary Motion.

Science Understanding	Possible contexts
<p>Centripetal acceleration occurs when the acceleration of an object is perpendicular to the velocity of the object. An object that experiences centripetal acceleration undergoes uniform circular motion. The centripetal acceleration is directed towards the centre of the circular path.</p> <p>The magnitude of the centripetal acceleration is constant for a given speed and radius and is given by $a = \frac{v^2}{r}$.</p> <p>The formula $v = \frac{2\pi r}{T}$ relates the speed, v, to the period, T, for an object undergoing circular motion with radius, r.</p> <ul style="list-style-type: none"> Solve problems involving the use of the formulae $a = \frac{v^2}{r}$, $v = \frac{2\pi r}{T}$, and $F = ma$. Use vector subtraction to show that the change in the velocity, $\Delta \mathbf{v}$, and hence the acceleration, of an object over a very small time interval is directed towards the centre of the circular path. <p>On a flat curve, the friction force between the tyres and the road causes the centripetal acceleration. To improve safety, some roads are banked at an angle above the horizontal.</p> <ul style="list-style-type: none"> Draw a diagram showing the force vectors (and their components) for a vehicle travelling around a flat curve and around a banked curve. Explain how a banked curve reduces the reliance on friction to provide centripetal acceleration. 	<p><i>This uses the concepts of acceleration and force developed in Stage 1, Subtopics 1.1: Motion under constant acceleration and 1.2: Forces.</i></p> <p>Describe situations in which the centripetal acceleration is caused by a tension force, a frictional force, a gravitational force, or a normal force.</p> <p>Investigate the force causing centripetal acceleration, using a tube, stopper, washers, and connecting string.</p> <p>Find and test the speed required for a marble to 'loop the loop', using flexible railing or a slot-car set.</p> <p>Explore the benefits and limitations in the design and use of banked curves, such as in velodromes, motor racing circuits, amusement park rides, and high-speed train tracks.</p>


Science Understanding	Possible contexts
<p>Objects with mass produce a gravitational field in the space that surrounds them.</p> <p>An object with mass experiences a gravitational force when it is within the gravitational field of another mass. Gravitational field strength, g, is defined as the net force per unit mass at a particular point in the field.</p> <p>This definition is expressed quantitatively as $g = \frac{F}{m}$, hence it is equal to the acceleration due to gravity. The magnitude of the acceleration due to gravity at the surface of the Earth is 9.80 m s^{-2}.</p> <p>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.</p> <p>Every particle in the universe attracts every other particle with a force that is directly proportional to the product of the two masses and inversely proportional to the square of the distance between their centres.</p> <p>The force between two masses, m_1 and m_2, separated by distance, r, is given by:</p> $F = G \frac{m_1 m_2}{r^2}$ <ul style="list-style-type: none"> • Solve problems using Newton's Universal Law of Gravitation. • Use proportionality to discuss changes in the magnitude of the gravitational force on each of the masses as a result of a change in one or both of the masses and/or a change in the distance between them. • Explain that the gravitational forces are consistent with Newton's Third Law. • Use Newton's Law of Universal Gravitation and Second Law of Motion to calculate the value of the acceleration due to gravity, g, on a planet or moon. 	<p>Use Newton's Law of Universal Gravitation to determine variations in acceleration due to gravity at different points on the surface of the Earth. For example, compare the gravitational acceleration at sea level to the top of Mt Everest.</p> <p>Use Newton's Law of Universal Gravitation to find the point between the Earth and the Moon where the net gravitational force is zero.</p> 



Science Understanding	Possible contexts	
<p>Many satellites orbit the Earth in circular orbits.</p> <ul style="list-style-type: none"> Explain why the centres of the circular orbits of Earth satellites must coincide with the centre of the Earth. Explain that the speed, and hence the period, of a satellite moving in a circular orbit depends only on the radius of the orbit and the mass of the central body (m_2) about which the satellite is orbiting and not on the mass of the satellite. Derive the formula $v = \sqrt{\frac{GM}{r}}$ for the speed, v, of a satellite moving in a circular orbit of radius, r, about a spherically symmetric mass, M, given that its gravitational effects are the same as if all its mass were located at its centre. <p>Kepler's Laws of Planetary Motion describe the motion of planets, their moons, and other satellites.</p> <p>Kepler's First Law of Planetary Motion: All planets move in elliptical orbits with the Sun at one focus.</p> <p>Kepler's Second Law of Planetary Motion: The radius vector drawn from the Sun to a planet sweeps equal areas in equal time intervals.</p> <ul style="list-style-type: none"> Use Kepler's first two laws to solve problems involving the motion of comets, planets, moons, and other satellites. <p>Kepler's Third Law of Planetary Motion shows that the period of any satellite depends upon the radius of its orbit.</p> <p>For circular orbits, Kepler's Third Law can be expressed as: $T^2 = \frac{4\pi^2}{GM} r^3$.</p> <ul style="list-style-type: none"> Derive: $T^2 = \frac{4\pi^2}{GM} r^3$ 	<p>Use Kepler's Laws to explain the motion of comets and predict times when they may be seen.</p> <p>Use data giving the orbital radii and periods of the natural satellites of a planet to determine the mass of the planet (e.g. for Saturn). Use similar techniques to determine the mass of the Sun.</p> <p>Explore the geometric definition of an ellipse and its relation to planetary and satellite motion.</p> <p>Investigate the eccentricities of planets within the solar system to explore how Kepler's Laws may be modelled as uniform circular motion.</p> <p>Track satellites in real time at: http://www.n2yo.com/?s=00050</p> <p>Analyse how the models for the motion of planets, stars, and other bodies were modified in the light of new evidence.</p> <p>Research the benefits, limitations, and/or unexpected consequences of the uses of satellites. Examples include: the Hubble Space Telescope, the International Space Station, GPS satellites, and decommissioned satellites.</p> <p>Use Kepler's Laws to analyse highly elliptical orbits, such as HD 80606 b and HD 20782. Consider the effect of these orbits on the composition and temperature changes on these exoplanets.</p> <p>Useful websites: http://news.mit.edu/2016/highly-eccentric-extreme-weather-exoplanet-0328 http://www.sci-news.com/astronomy/hd20782b-exoplanet-highly-eccentric-orbit-03718.html</p> <p>Investigate how Kepler's Laws can be used to estimate the mass of black holes, including Sagittarius A* — the black hole hypothesised to exist within the Milky Way Galaxy.</p>	  

Science Understanding	Possible contexts	
<ul style="list-style-type: none"> Solve problems involving the use of the formulae $v = \sqrt{\frac{GM}{r}}$, $v = \frac{2\pi r}{T}$, and $T^2 = \frac{4\pi^2}{GM} r^3$. Explain why a satellite in a geostationary orbit must have an orbit in the Earth's equatorial plane, with a relatively large radius and in the same direction as the Earth's rotation. Explain the differences between polar, geostationary, and equatorial orbits. Justify the use of each orbit for different applications. Perform calculations involving orbital periods, radii, altitudes above the surface, and speeds of satellites, including examples that involve the orbits of geostationary satellites. 	<p>Useful websites:</p> <p>http://curious.astro.cornell.edu/about-us/95-the-universe/galaxies/general-questions/512-do-stars-orbits-in-galaxies-obey-kepler-s-laws-intermediate</p> <p>http://io9.gizmodo.com/the-video-that-revealed-the-black-hole-at-the-center-of-1114918644</p>	

Subtopic 1.4: Relativity

Students explore how Einstein's Theory of Special Relativity can be used to explain the behaviour of objects at high speeds. The theory is based on two postulates: the postulate of the constancy of the speed of the light, and the postulate that there is no preferred frame of reference. Students describe, predict, and calculate some of the counter-intuitive consequences of the theory, as well as explore some of the experiments that support the theory.

Science Understanding	Possible contexts
<p>Motion can only be measured relative to an observer; length and time are relative quantities that depend on the observer's frame of reference.</p> <p>Some measured quantities of objects travelling at very high speeds cannot be explained by Newtonian physics. Einstein's Theory of Special Relativity predicts significantly different results to those of Newtonian physics for velocities approaching the speed of light.</p> <p>The Theory of Special Relativity is based on two postulates. The first postulate is that the laws of physics are the same in all inertial reference frames. The second postulate is that the speed of light in a vacuum is an absolute constant.</p> <p>In relativistic mechanics, there is no absolute length or time interval.</p> <p>At relativistic speeds, time intervals in moving frames of reference are dilated when observed from a stationary reference frame according to $t = \gamma t_0$ where</p> $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ <p>γ is the Lorentz factor, t_0 is the time interval in the moving frame of reference and t is the time interval in the stationary observer's frame of reference.</p> <ul style="list-style-type: none"> Solve problems using $t = \gamma t_0$ and the Lorentz factor formula. Explain the effects of time dilation on objects moving at relativistic speeds. 	<p>Investigate different frames of reference, for example:</p> <ul style="list-style-type: none"> the motion of a ball being thrown vertically inside a moving train from the perspective of a stationary person on the train can be compared to an observer standing on the ground. the motion of a projectile moving with the same horizontal speed as a moving vehicle (relative to the ground) can be compared using perspectives from the ground and the moving vehicle. <p>Use graphical representations of the motion of Mars to demonstrate and explain its retrograde motion to show different frames of reference.</p> <p>Use the formula for relativistic momentum to explain why it is impossible for an object to travel faster than light: https://www.youtube.com/watch?v=wteixuyqtoM</p> <p>Explore the time dilation effects that have been measured experimentally with atomic caesium clocks.</p> <p>Use the twin paradox to describe time dilation and the implications for long-distance space travel.</p> <p>Discuss the difficulties surrounding providing experimental evidence of length contraction. There is an indirect way to measure the relativistic effects of length contraction in relation to magnetism: https://www.youtube.com/watch?v=1TKSfAkWWN0</p> <p>The book <i>Mr Tomkins in Wonderland</i> by George Gamow provides an accessible qualitative description of special relativity if it were experienced at low speeds.</p> 

Science Understanding	Possible contexts	
<p>Some subatomic particles exist in the laboratory for very short time periods before decaying. These same particles are detected as part of cosmic ray showers in the atmosphere, travelling at relativistic speeds close to the speed of light.</p> <p>Time dilation effects allow these particles to travel significant distances without decay.</p> <ul style="list-style-type: none"> Calculate and compare lifetimes and therefore distances travelled by subatomic particles in stationary and moving reference frames. Solve problems involving subatomic particles moving at relativistic speeds. <p>An object moving at relativistic speeds is shorter to an observer in a stationary frame of reference, and the length is given by:</p> $l = \frac{l_0}{\gamma}, \text{ where } l_0 \text{ is the length in the}$ <p>moving object's frame of reference and l is the length in the stationary observer's frame of reference.</p> <ul style="list-style-type: none"> Solve problems using $l = \frac{l_0}{\gamma}$. Explain the effects of length contraction on objects moving at relativistic speeds. <p>The magnitude of the relativistic momentum of a moving object is given by $p = \gamma m_0 v$, where m_0 is the mass of the object in the frame of reference where the object is stationary and v is the speed of the object.</p> <ul style="list-style-type: none"> Solve problems using $p = \gamma m_0 v$. Explain why masses moving at relativistic speeds are unable to reach the speed of light. 	<p>Investigate how relativistic effects are taken into consideration in the Global Positioning System (GPS):</p> <p>http://www.brighthub.com/science/space/articles/32969.aspx</p> <p>http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit5/gps.html</p>	
	<p>Explore how new evidence led scientists to modify models to account for high-speed particles which exhibited properties that were inconsistent with Newtonian physics.</p> <p>In what way has the evidence from different sources, such as X-rays from binary star systems and other experiments on moving gamma radiation sources, supported Einstein's second postulate of relativity?</p> <p>What happens if you try to apply the equation for the relativistic momentum of a moving object to a photon? Explain in terms of the postulates of special relativity.</p>	

Topic 2: Electricity and magnetism

This topic builds on the concepts of circuit electricity developed in Stage 1, Topic 2: Electric circuits and projectile and circular motion developed in Stage 2, Topic 1: Motion and relativity. It introduces students to the use of the concept of fields in physics. The conventions adopted to represent fields pictorially show the magnitude and direction of the relevant field vectors at points within the field. Students discuss forces between stationary charges. They analyse the motion of charged particles in uniform electric fields quantitatively, in one and two dimensions. They make comparisons with projectile motion, as described in Stage 2, Topic 1: Motion and relativity.

Students examine moving charges, first in electric currents and then in a vacuum. A magnetic field is shown to exist in each case. This magnetic field can exert a force on another electric current or a charge moving in a vacuum. In the latter case, the force can cause the charge to move uniformly in a circle. The quantitative analysis of this motion involves the ideas of uniform circular motion developed in Stage 2, Topic 1: Motion and relativity.

The limitation on the maximum energy of the ions exiting a cyclotron due to relativistic effects builds on concepts introduced in Stage 2, Topic 1: Motion and relativity. The production of high-intensity and high-frequency light in a synchrotron links this topic to the production of electromagnetic radiation in Stage 2, Topic 3: Light and atoms.

Data capture, storage, transmission, and reproduction rely on electricity and magnetism and can be used as the context through which students can develop their information and communication technology capability.




Examples of the application of electricity and magnetism in medical physics include the use of shielding of NMR rooms, the use of linear accelerators and X-ray tubes, and the production of medical radioisotopes. Each of these settings extends the personal and social capability as students better understand the importance of physics to health and well-being.




Calculations involving electrostatic forces and the motion of charged particles in electric and magnetic fields extend the numeracy capabilities of students.



Subtopic 2.1: Electric fields

Students are introduced to two fundamental postulates of electrostatics: Coulomb's Law and the principle of superposition. The electric field at a point in space is defined and used, with Coulomb's Law, to derive a formula for the electric field at a distance from a point charge. In this topic the charges are assumed to be in a vacuum (or, for practical purposes, air).

Students explore several important electric field distributions, including those used in a wide range of applications.

Science Understanding	Possible contexts	
<p>Electrostatically charged objects exert forces upon one another; the magnitude of these forces can be calculated using Coulomb's Law.</p> <ul style="list-style-type: none"> Solve problems involving the use of: $F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}.$ Using proportionality, discuss changes in the magnitude of the force on each of the charges as a result of a change in one or both of the charges and/or a change in the distance between them. Describe how the electric forces are consistent with Newton's Third Law. 	<p><i>This uses the concepts of force developed in Stage 1, Subtopic 1.2: Forces and charge in Subtopic 2.1: Potential difference and electric current.</i></p> <p>Compare and contrast Coulomb's Law with Newton's Law of Universal Gravitation.</p> <p>Use a Van de Graaff generator to demonstrate repulsion between like charges.</p>	
	<p>Explore an example of the development of complex models using evidence from many sources using the video, 'Coulomb's Law': https://youtu.be/B5LVoU_a08c</p>	
<p>When more than two point charges are present, the force on any one of them is equal to the vector sum of the forces due to each of the other point charges.</p> <ul style="list-style-type: none"> Use vector addition in one dimension or two dimensions (with right-angled, or equilateral triangles) to calculate the magnitude and direction of the force on a point charge due to two other point charges. 	<p><i>The Principle of Superposition is a key concept in this topic and in Stage 2, Topic 3, Light and atoms. It is essential here when sketching electric field diagrams, particularly of two charges or two parallel plates.</i></p>	


Science Understanding	Possible contexts	
<p>Point charges and charged objects produce electric fields in the space that surrounds them. A charged object in an electric field experiences an electric force.</p> <p>The direction and number of electric field lines per unit area represent the direction and magnitude of the electric field.</p> <ul style="list-style-type: none"> Sketch the electric field lines: <ul style="list-style-type: none"> for an isolated positive or negative point charge and for two point charges between and near the edges of two finite oppositely charged parallel plates. 	<p>Computer interactive: 'Electric Fields and Charges' from: https://phet.colorado.edu/en/simulation/charges-and-fields</p> <p>Demonstrate electric fields using an HT (high tension) power supply or a Van de Graaff generator.</p> <p>Explore applications of electric fields, such as:</p> <ul style="list-style-type: none"> electrostatic loudspeakers shark shields capacitors. 	
<p>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.</p> <ul style="list-style-type: none"> Solve problems involving the use of: $\vec{E} = \frac{\vec{F}}{q}$ Using Coulomb's Law, derive the formula: $E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$ Solve problems using: $E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$, for one isolated point charge. Use vector addition in one dimension or in two dimensions (with right-angled or equilateral triangles) to determine the magnitude and direction of an electric field due to two point charges. 	<p>Use electric field sensors to map electric fields and explore the relationship between electric field strength and distance from charged conductors.</p>	
<p>There is no electric field inside a hollow conductor of any shape, provided that there is no charge in the cavity.</p> <ul style="list-style-type: none"> Sketch the electric field produced by a hollow spherical charged conductor. 	<p>Assess the benefits and limitations of applications of electrostatic shielding.</p> <p>Examples include:</p> <ul style="list-style-type: none"> Faraday cages microwave ovens NMR (nuclear magnetic resonance) imaging rooms coaxial and USB cables difficulties with mobile phone reception. 	


Science Understanding	Possible contexts	
<p>Electric fields are strongest near sharp points on conductors. These fields may be large enough to ionise molecules in the air near the sharp points, resulting in charge movement away from the conductor. This is called a 'corona discharge'.</p> <ul style="list-style-type: none"> • Sketch the electric field produced by charged conductors of an irregular shape. • Explain how the electric field near sharp points may ionise the air. 	<p>Demonstrate corona discharges using a Van de Graaff generator.</p>	
	<p>Explore problems for which scientists have developed practical solutions by making use of strong electric fields. Examples include:</p> <ul style="list-style-type: none"> • photocopier (charging drum and charging/discharging paper) • lightning rod • electrostatic precipitator • spark plugs. 	



Subtopic 2.2: Motion of charged particles in electric fields

Students are introduced to the concept of work done by an electric field on a charged particle. The potential difference between two points in an electric field is defined and used to determine the work, and hence energy changes, of charged particles moving in uniform electric fields in a vacuum.

Students use formulae to determine the electric force and hence the resulting motion of charged particles in uniform electric fields. Students use the electric field and electric force concepts to explore the motion of ions in particle accelerators, such as a cyclotron.





Science Understanding	Possible contexts
<p>When a charged body moves or is moved from one point to another in an electric field, work is done on or by the field.</p> <p>The electric potential difference, ΔV, between two points is the work done per unit charge on a small positive test charge moved between the points, provided that all other charges remain undisturbed.</p> <p>The electronvolt (eV) is a unit of measurement which describes the energy carried by a particle. It is the work done when an electron moves through a potential difference of 1 volt.</p> <ul style="list-style-type: none"> Solve problems involving the use of $W = q\Delta V$. Convert energy values between joules and electronvolts. <p>The magnitude of the electric field (away from the edges) between two oppositely charged parallel plates a distance d apart, where ΔV is the potential difference between the plates, is given by the formula:</p> $E = \frac{\Delta V}{d}.$ <ul style="list-style-type: none"> Solve problems involving the use of $E = \frac{\Delta V}{d}.$ 	<p><i>This uses the concepts of force developed in Stage 1, Subtopic 1.2: Forces and energy in Stage 1, Subtopic 4.1: Energy.</i></p> <p>Use the concepts of work done and gravitational potential energy to introduce the concepts of electric potential energy and potential difference.</p> <p><i>The energy conversions relating to this concept have relevance to several other sections in the subject outline, including:</i></p> <ul style="list-style-type: none"> Stage 2, Subtopic 1.2: Forces and momentum: ion thrusters Stage 2, Subtopic 3.2: Wave-particle duality: particle accelerators, X-ray production, the photoelectric effect, the Davisson-Germer experiment Stage 2, Subtopic 3.3: The structure of the atom: production of line emission spectra. <p>The meaning of the formula $W = q\Delta V$ should be emphasised in each context.</p> <p>Discuss the convenience of the different energy units (J and eV) in different circumstances.</p> 

Science Understanding	Possible contexts	
<p>The force on a charged particle moving in a uniform electric field is constant in magnitude and direction, thus producing a constant acceleration.</p> <ul style="list-style-type: none"> Derive the formula $\vec{a} = \frac{q\vec{E}}{m}$ for the acceleration of a charged particle in an electric field. Solve problems using $\vec{a} = \frac{q\vec{E}}{m}$ and the constant acceleration formulae for charged particles moving parallel or antiparallel to a uniform electric field. Describe the motion of charged particles moving parallel or antiparallel to a uniform electric field. <p>In a cyclotron, the electric field in the gap between the dees increases the speed of the charged particles.</p> <ul style="list-style-type: none"> Describe how an electric field between the dees can transfer energy to a charged particle passing between them. Describe how charged particles could be accelerated to high energies if they could be made to repeatedly move across an electric field. Calculate the energy transferred to a charged particle each time it passes between the dees. Explain why charged particles do not gain kinetic energy when inside the dees. 	<p>Explore solutions to scientific problems developed using the motion of charges parallel or antiparallel to electric fields, such as:</p> <ul style="list-style-type: none"> linear accelerators electron guns (e.g. in electron microscopes, oscilloscopes) ion thrusters (e.g. in spacecraft propulsion) X-ray tubes (e.g. in medicine). 	

<p>A charged particle moving at an angle to a uniform electric field experiences a force which affects both components of its velocity differently. The component of the velocity parallel to the electric field changes due the electric force and the component perpendicular to the field remains constant.</p> <ul style="list-style-type: none">• Compare the motion of a projectile in the absence of air resistance with the motion of a charged particle in a uniform electric field.• Solve problems for the motion of charged particles that enter a uniform electric field perpendicular to the field.• Solve problems for the motion of charged particles that enter a uniform electric field at an angle to the field where the displacement of the charged particle parallel to the field is zero.	<p><i>Reinforce the concepts and processes introduced in Stage 2, Subtopic 1.2: Projectile motion.</i></p>	
	<p>Investigate the motion of electrons in an electric field using Teltron tubes.</p>	

Subtopic 2.3: Magnetic fields

Students are introduced to the concept that a moving charge produces a magnetic field in addition to its electric field. The magnetic field strength at a point in space is defined and used. The interaction between magnetic fields and electric currents is described and used to define the strength of the magnetic field in terms of the force on current-carrying conductors.



Science Understanding	Possible contexts	
<p>Magnetic fields are associated with permanent magnets and moving charges, such as charges in an electric current.</p> <p>Current-carrying conductors produce magnetic fields; these fields are utilised in solenoids.</p> <p>Magnetic field lines can be used to represent the magnetic field. The direction of the magnetic field depends on the direction of the moving charge that is producing the magnetic field.</p> <p>The direction and number of magnetic field lines per unit area represent the direction and magnitude of the magnetic field.</p> <ul style="list-style-type: none"> Sketch and/or interpret the magnetic field lines produced by a bar magnet, and an electric current flowing in a straight conductor, a loop, and a solenoid. 	<p><i>This uses the concept of electric current developed in Stage 1, Subtopic 2.1: Potential difference and electric current.</i></p> <p>Demonstrate magnetic field lines around permanent magnets, current-carrying conductors, and solenoids.</p>	
	<p>Investigate electromagnets and their uses.</p> <p>Determine the direction of magnetic fields using a 'right-hand rule'.</p> <p>Investigate factors affecting magnetic field strength near a solenoid.</p>	
<p>The magnitude of the magnetic field strength, B, at a radial distance, r, from the centre of a current-carrying conductor is given by $B = \frac{\mu_0 I}{2\pi r}$.</p> <ul style="list-style-type: none"> Solve problems involving the use of $B = \frac{\mu_0 I}{2\pi r}$. Use vector addition in one dimension or in two dimensions (with right-angled or equilateral triangles) to calculate the magnitude and direction of the magnetic field due to two current-carrying conductors) 	<p>Compare and contrast the factors affecting gravitational field strength, electric field strength, and magnetic field strength.</p>	
	<p>Use sensors to measure the magnitude of the magnetic field strength at different distances from or different currents in conductors, loops, and solenoids.</p>	

Subtopic 2.4: Motion of charged particles in magnetic fields

The interaction of current-carrying conductors and magnetic fields is extended to the interaction of moving charged particles and uniform magnetic fields. Students investigate applications of the magnetic force on a current-carrying conductor.

Students explore the velocity dependence of the magnetic force on a moving charged particle, comparing this with the electric force. They discuss the circular path of charged particles moving at right angles to a uniform magnetic field, and apply their understanding to the deflection of ions in applications such as a cyclotron.





Science Understanding	Possible contexts
<p>Magnets, magnetic materials, moving charges, and current-carrying conductors experience a force in a magnetic field.</p> <p>The magnetic force on a moving charged particle within a uniform magnetic field depends on the velocity of the particle, its charge, the magnetic field, and the angle between the velocity and magnetic field.</p> <p>The force on a current-carrying conductor within a uniform magnetic field depends on the current in the conductor, the length of the conductor within the magnetic field, the magnetic field strength, and the angle between the conductor and magnetic field.</p> <ul style="list-style-type: none"> Determine the direction of one of: <ul style="list-style-type: none"> force magnetic field charge movement given the direction of the other two. Solve problems involving the use of $F = IlB \sin \theta$ for a current-carrying conductor and $F = qvB \sin \theta$ for a moving charged particle. <p>A charged particle moving at right angles to a uniform magnetic field experiences a force of constant magnitude at right angles to the velocity. The force changes the direction but not the speed of the charged particle, therefore causes centripetal acceleration.</p> <ul style="list-style-type: none"> Explain how the velocity dependence of the magnetic force on a charged particle causes the particle to move with uniform circular motion when it enters a uniform magnetic field at right angles. 	<p><i>This uses the concept of force developed in Stage 1, Subtopic 1.2: Forces and the concept of circular motion in Stage 2, Subtopic 1.3: Circular motion and gravitation.</i></p> <p>Demonstrate the production of sound in loudspeakers.</p> <p>Use a current balance to determine the force on current-carrying conductors due to an external magnetic field.</p> <p>Investigate the motion of charges using Teltron tube or fine-beam apparatus.</p> <p>Use Teltron tubes to measure the charge-to-mass ratio of electrons.</p> <p>Evaluate the economic, social, and environmental impacts of some applications of charges moving within magnetic fields, such as:</p> <ul style="list-style-type: none"> moving-coil loudspeaker synchrotron mass spectrometer electric motors use of magnetic fields in electron microscopes. maglev trains.

Science Understanding	Possible contexts	
<ul style="list-style-type: none"> Derive $r = \frac{mv}{qB}$ for the radius r of the circular path of an ion of charge q and mass m that is moving with speed v at right angles to a uniform magnetic field of magnitude B. Solve problems involving the use of $r = \frac{mv}{qB}$. 		
<p>Cyclotrons are used to accelerate ions to high speed. Radioisotopes used in medicine and industry may be produced from collisions between high-speed ions and nuclei.</p>	<p>Discuss the advantages and disadvantages of generating radioisotopes in a cyclotron compared to a nuclear reactor. Make recommendations for particular contexts.</p> <p>Debate the need for both cyclotrons and nuclear reactors in the production of radioisotopes, including the relationship between public debate and science.</p> <p>Discuss the importance of the cyclotron in the South Australian Health and Medical Research Institute (SAHMRI) facility.</p> <p>Investigate medical uses and disadvantages of radioisotopes for diagnostic and therapeutic purposes (e.g. PET scanners, boron neutron capture therapy).</p> <p>Investigate benefits and limitations of using radioisotopes in industry (e.g. in quality assurance processes).</p> <p>Discuss the safe storage and disposal of radioactive materials.</p>	
<p>The magnetic field within the dees of a cyclotron causes the charged particles to travel in a circular path, so that they repeatedly pass through the electric field.</p> <ul style="list-style-type: none"> Describe the nature and direction of the magnetic field needed to deflect ions into a circular path in the dees of a cyclotron. Derive the formula $T = \frac{2\pi m}{qB}$ for the period T of the circular motion of an ion, and hence show that the period is independent of the speed of the ion. 	<p>Study the production and use of radioisotopes, for medical or industrial use.</p> <p>Explore the limitation on the energy of a charged particle emerging from a cyclotron due to relativistic effects.</p>	

Science Understanding	Possible contexts	
<ul style="list-style-type: none"> Use $f = \frac{1}{T}$ to relate the period to the frequency of the alternating potential differences. Derive the formula $E_K = \frac{q^2 B^2 r^2}{2m}$ for the kinetic energy E_K of the ions emerging at radius r from a cyclotron. Explain why E_K is independent of the potential difference across the dees and, for given ions, depends only on the magnetic field and the radius of the cyclotron. Solve problems involving the use of $T = \frac{2\pi m}{qB}$ and $E_K = \frac{q^2 B^2 r^2}{2m}$. 		

Subtopic 2.5: Electromagnetic induction

Students are introduced to the concepts of magnetic flux and induced electromotive force. They use Faraday's Law and Lenz's Law to investigate and explain a range of applications, such as electrical generators, induction stoves, and transformers.

Science Understanding	Possible contexts	
<p>Magnetic flux (Φ) is defined as the product of magnetic field strength (B) and the area perpendicular to the magnetic field (A_{\perp}).</p> <p>Hence: $\Phi = BA_{\perp}$.</p> <ul style="list-style-type: none"> Solve problems involving the use of $\Phi = BA_{\perp}$. 	<p><i>This uses the concept of electric current developed in Stage 1, Subtopic 2.1: Potential difference and electric current.</i></p>	
<p>Electromagnetic induction is the process in which a changing magnetic flux induces a potential difference in a conductor.</p> <p>The induced potential difference is referred to as an electromotive force (\mathcal{E}).</p> <p>The changing magnetic flux is due to relative movement of the conductor or variation of the magnetic field strength.</p> <p>Faraday's Law states that the induced emf is equal to the rate of change of the magnetic flux.</p> <p>For N conducting loops the induced \mathcal{E} is given by $\mathcal{E} = \frac{N\Delta\Phi}{\Delta t}$.</p> <p>Lenz's Law states that the direction of a current created by an induced \mathcal{E} is such that it opposes the change in magnetic flux producing the \mathcal{E}.</p> <ul style="list-style-type: none"> Solve problems involving the induction of an \mathcal{E} in a straight conductor. Solve problems involving the induction of an \mathcal{E} in N conducting loops. Use the law of conservation of energy to explain Lenz's Law. Use Lenz's Law to determine the direction of the current produced by the induced \mathcal{E}. Use Lenz's Law to explain the production of eddy currents. 	<p>Computer interactives:</p> <ul style="list-style-type: none"> 'Faraday's Law' from https://phet.colorado.edu/en/simulation/faradays-law 'Faraday's Electromagnetic Lab' from https://phet.colorado.edu/en/simulation/faraday. <p>Demonstrate an induction coil and floating ring, Ruhmkorff coil and spark, and/or magnet falling through a copper pipe.</p>	
	<p>Investigate induced <i>emf</i> and currents using data loggers.</p> <p>Investigate the output of a hand-turned generator.</p> <p>Compare the structure and function of a generator to an electric motor.</p>	
	<p>Explore the benefits and limitations of applications of electromagnetic induction, such as:</p> <ul style="list-style-type: none"> reading data from computer hard drives induction cooktops electromagnetic (eddy-current) braking maglev trains security systems vehicle detection at traffic lights metal detectors minesweepers. 	

Science Understanding	Possible contexts	
<p>Some generators use a fixed magnet to generate <i>emfs</i> in rotating conducting loops for electricity production.</p> <ul style="list-style-type: none"> Explain how generators can be used to produce an alternating electric current. <p>Transformers allow generated voltage to be either increased or decreased before it is used. A transformer consists of an input coil (with N_{input} turns) with a potential difference V_{input} and an output coil (with N_{output} turns) with a potential difference V_{output}.</p> <p>The relationship between the potential differences is given by the formula:</p> $\frac{V_{input}}{V_{output}} = \frac{N_{input}}{N_{output}}.$ <ul style="list-style-type: none"> Describe the purpose of transformers in electrical circuits. Explain how a transformer increases or decreases an alternating potential difference. Compare step-up and step-down transformers. Solve problems involving the use of: $\frac{V_{input}}{V_{output}} = \frac{N_{input}}{N_{output}}.$	<p>Assess the economic, social, and environmental impacts of power generation by:</p> <ul style="list-style-type: none"> mechanically powered torches domestic and industrial electricity power stations alternators in vehicles. <p>Analyse changes that have resulted from the use of transformers in contexts such as:</p> <ul style="list-style-type: none"> step-up and step-down transformers in electrical power transmission step-down transformers in home appliances induction coils in vehicles. 	



Topic 3: Light and atoms

Light, and other forms of electromagnetic radiation, represent one of the most important forms of energy transfer. Analysis of light is crucial to developing an understanding of the structure of matter. The mass–energy equivalence also explains the large amount of energy that can be produced in nuclear reactions.

Light and matter exhibit the characteristics of both waves and matter. Interference patterns can be explained using the wave model of light and the applications of interference enhance students' understanding of information and communication technology.

The wave model of light cannot explain phenomena such as the behaviour of light at relatively low intensities and the photoelectric effect. To explain these phenomena, light must be considered in terms of the photon model. The production of X-rays is also explained in terms of photons. The interference of electrons is used to introduce the concept of the wave behaviour of particles. By describing and explaining these phenomena, students extend their literacy capability.





The emission and absorption of light by matter can be used to explain the structure of the atom and concepts such as fluorescence, stimulated emission, and black-body radiation.








The ethical understanding of students will be strengthened as they recognise the need to make ethical decisions based on their further understanding of ionising radiation.



Subtopic 3.1: Wave behaviour of light


Students explore applications that use oscillating charges to radiate electromagnetic waves, which propagate at the speed of light. They discuss the link between electromagnetism and light, and relate the frequency and polarisation of television and radio waves to the frequency and direction of oscillation of the electrons in an antenna.

Students use the wave model of light to explain interference and diffraction. Diffraction is treated qualitatively as a precursor to a more extended quantitative treatment of the interference of light from two slits. This is extended to the transmission diffraction grating and its uses.

Science Understanding	Possible contexts	
<p>Oscillating charges produce electromagnetic waves of the same frequency as the oscillation; electromagnetic waves cause charges to oscillate at the frequency of the wave.</p> <ul style="list-style-type: none"> Use the frequency of oscillation of the electrons in the transmitting and receiving antennae to explain the transmission and reception of electromagnetic signals. <p>Electromagnetic waves are transverse waves made up of mutually perpendicular, oscillating electric and magnetic fields.</p> <ul style="list-style-type: none"> Relate the orientation of the receiving antenna to the plane of polarisation of electromagnetic waves. <p>The speed of a wave, its frequency, and its wavelength are related through the formula $v = f\lambda$.</p> <ul style="list-style-type: none"> Solve problems using $v = f\lambda$. 	<p><i>This uses the concept of waves developed in the Stage 1, Subtopics 5.1: Wave model and 5.3 Light.</i></p> <p>Demonstrate the polarisation of microwaves.</p> <p>Utilise computer interactive showing production and transmission of electromagnetic waves: https://phet.colorado.edu/en/simulation/legacy/radio-waves.</p>	
<p>Most light sources emit waves that radiate in all directions away from the source.</p> <p>Monochromatic light is light composed of a single frequency.</p> <p>Coherent waves maintain a constant phase relationship with each other.</p> <ul style="list-style-type: none"> Describe what is meant by two wave sources being in phase or out of phase. Explain why light from an incandescent source is neither coherent nor monochromatic. 	<p>Explore examples of new technologies enabled by an understanding of electromagnetic waves:</p> <ul style="list-style-type: none"> data recording, storage, transmission, and reproduction AM and FM radio/TV mobile phone transmission, Bluetooth, Wi-Fi orientation of transmitting and receiving antennae synchrotron radiation. 	
	<p>Illustrate examples of wave sources that are in phase and out of phase.</p>	
	<p>Observe spectra of light from various sources (e.g. incandescent globe, fluorescent globe, vapour lamp, LED) through a spectroscope.</p>	





Science Understanding	Possible contexts
<p>When two or more electromagnetic waves overlap, the resultant electric and magnetic fields at a point can be determined using the principle of superposition.</p> <p>When the waves at a point are in phase, 'constructive interference' occurs.</p> <p>When the waves at a point are out of phase, 'destructive interference' occurs.</p> <ul style="list-style-type: none"> Use the principle of superposition to describe and represent constructive and destructive interference. 	<p>Illustrate examples of constructive and destructive interference.</p> <p>Investigate interference patterns produced by light using, e.g. thin films, multiple wave-sources, and multiple layers of nanoparticles.</p> 
<p>For two monochromatic sources in phase, the waves at a point some distance away in a vacuum:</p> <ul style="list-style-type: none"> constructively interfere when the path difference from the sources to the point is $m\lambda$ destructively interfere when the path difference from the sources to the point is $(m + \frac{1}{2})\lambda$ <p>where m is an integer and λ is the wavelength.</p> <ul style="list-style-type: none"> Use the principle of superposition to determine points of maximum or minimum amplitude resulting from the interference of light from two wave sources of the same frequency. Use constructive and destructive interference to explain the maximum and minimum amplitudes. 	<p>Explore opportunities for innovation provided by applying the interference of electromagnetic waves in applications such as Blu-ray players and anti-reflective surfaces.</p> 
<p>Young's double-slit experiment can be used to demonstrate the wave behaviour of light.</p> <p>The formulae $d \sin \theta = m\lambda$ and $\Delta y = \frac{\lambda L}{d}$ can be used to analyse the interference pattern, where d is the distance between the slits, θ is the angular position of the maximum, Δy is the distance between adjacent minima or maxima on the screen, and L is the slit-to-screen distance.</p> <ul style="list-style-type: none"> Describe how two-slit interference is produced in the laboratory using a coherent light. 	<p>Demonstrate a two-source interference pattern using a ripple tank or two-source simulation application: https://phet.colorado.edu/en/simulation/wave-interference</p> <p>Illustrate regions of constructive and destructive interference on a two-source diagram.</p> 
	<p>Explore the effect of frequency/ wavelength on a two-source interference pattern.</p> 
	<p>Demonstrate a two-slit interference pattern using laser and diffraction grating slide or simulation: https://phet.colorado.edu/en/simulation/wave-interference</p> 
	<p>Investigate the effect of slit separation on a two-slit interference pattern.</p> <p>Determine the wavelength from a two-source interference pattern.</p> 
	<p>Research the ways in which multiple lines of evidence have led to an understanding of the wave-particle duality of light.</p> 


Science Understanding	Possible contexts	
<ul style="list-style-type: none"> Describe how diffraction of the light by the slits in a two-slit interference apparatus allows the light to overlap and hence interfere. Sketch a graph of the intensity distribution for two-slit interference of monochromatic light. (Consider only cases where the slit separation is much greater than the width of the slits.) Explain the bright fringes of a two-slit interference pattern using constructive interference, and the dark fringes using destructive interference. Solve problems involving the use of $d \sin \theta = m\lambda$ and $\Delta y = \frac{\lambda L}{d}$. Determine the wavelength of monochromatic light from measurements of the two-slit interference pattern. 		
<p>The interference pattern produced by light passing through a transmission diffraction grating demonstrates the wave behaviour of light.</p> <p>Transmission diffraction gratings can be used to analyse the spectra of various light sources.</p> <p>The formula $d \sin \theta = m\lambda$ can be used to analyse the interference pattern.</p> <ul style="list-style-type: none"> Describe how diffraction by the very thin slits in a transmission diffraction grating allows the light from the slits to overlap and hence interfere to produce significant intensity maxima at large 	<p>Demonstrate an interference pattern produced by a transmission diffraction grating, using coherent light.</p> <p>Illustrate the geometric derivation for $d \sin \theta = m\lambda$ for a transmission diffraction pattern.</p> <p>Demonstrate an interference pattern produced by a transmission diffraction grating, using white light.</p>	
	<p>Determine the wavelength of a monochromatic source.</p> <p>Observe the spectra of different light sources.</p>	


Science Understanding	Possible contexts	
<p>angles.</p> <ul style="list-style-type: none"> Derive $d \sin \theta = m\lambda$ for the intensity maxima in the pattern produced by a transmission diffraction grating, where d is the distance between the slits in the grating and θ is the angular position of the m^{th} maximum (m specifies the order of the maximum). Solve problems involving the use of $d \sin \theta = m\lambda$. Sketch a graph of the intensity distribution of the maxima produced by a transmission diffraction grating, for monochromatic light. 	<p>Explore the emerging technologies which use optical data storage; consider the interplay with technology and engineering.</p>	
<ul style="list-style-type: none"> Determine, from the distance between the slits in the transmission diffraction grating, the maximum number of orders possible for a given transmission diffraction grating and wavelength. Describe how a transmission diffraction grating can be used to experimentally determine the wavelength of light from a monochromatic source. Describe and explain the white-light pattern produced by a transmission diffraction grating. Identify the properties of a transmission diffraction grating that make it useful in spectroscopy. 		




Subtopic 3.2: Wave–particle duality

Students compare the wave model of light to the particle model needed to explain the interaction of light with matter. The properties of photons are introduced and the phenomena of the photoelectric effect and X-rays are then examined and explained in terms of photons. In addition, the wave behaviour of particles, such as electrons, is also introduced. Students explore applications of photons, X-rays, and the wave behaviour of particles.

Science Understanding	Possible contexts
<p>In interacting with matter, light behaves like particles (called ‘photons’), with energy given by $E = hf$ and momentum given by $p = \frac{h}{\lambda}$, where h is Planck’s constant, f is the frequency of the light, and λ is its wavelength.</p> <ul style="list-style-type: none"> Solve problems using $E = hf$ and $p = \frac{h}{\lambda}$. 	<p><i>This uses the concepts of energy developed in Stage 1, Subtopic 4.1: Energy and Stage 2, Subtopic 2.2: Motion of charged particles in electric fields; momentum developed in Stage 1, Subtopic 4.2: Momentum; and waves developed in Stage 1, Subtopics 5.1: Wave model and 5.3: Light.</i></p> <p>Investigate photon by photon build-up of an interference pattern, using a simulation: https://phet.colorado.edu/en/simulation/quantum-wave-interference</p> <p>Describe how microscopic observations of the building up of an image produced by light of very low intensity demonstrate the arrival of localised bundles of energy and momentum called photons.</p> <p>Discuss the acceleration of solar sails as the result of the reflection of photons, emphasising that photons have momentum.</p> 
	<p>Explore ways in which engineers use an understanding of photons to design devices. Examples include:</p> <ul style="list-style-type: none"> charge-coupled devices in digital cameras photomultiplier tubes for neutrino detection inside huge underground water tanks. 
<p>Electrons may be emitted from a metal surface when light of sufficiently high frequency is incident on the metal surface. This process is called the ‘photoelectric effect’.</p> <p>If monochromatic light is used the intensity of the incident light affects the number, but not the energy, of emitted electrons.</p>	<p>Discuss the photoelectric experiment: https://phet.colorado.edu/en/simulation/photoelectric</p> <p>Explain why the wave model of light cannot explain results of the photoelectric experiment.</p> 
	<p>Investigate the photoelectric effect experimentally.</p> 

Science Understanding	Possible contexts	
<p>The minimum frequency, f_0, at which electrons are emitted varies with the type of material and is called the 'threshold frequency'.</p> <p>The work function, W, of a surface is the minimum energy required to remove an electron from it.</p> <p>The work function is related to the threshold frequency by $W = hf_0$.</p> <ul style="list-style-type: none"> Describe an experimental method for investigating the relationship between the maximum kinetic energy of the emitted electrons, calculated from the measured stopping voltage using $E_{K_{\max}} = eV_s$ and the frequency of the light incident on a metal surface. Describe how Einstein used the concept of photons and the conservation of energy to explain the experimental observations of the photoelectric effect. Deduce the formula $E_{K_{\max}} = hf - W$ where $E_{K_{\max}}$ is the maximum kinetic energy of the emitted electrons. Plot experimental values of maximum kinetic energy vs frequency, and relate the slope and axes intercepts to the formula: $E_{K_{\max}} = hf - W$. Solve problems that require the use of $E_{K_{\max}} = hf - W$. 	<p>Explore innovations which utilise the photoelectric effect, for example:</p> <ul style="list-style-type: none"> solar cells photocells (used as light sensors in cameras and many other automated electronic and security systems) photomultiplier tubes used in many scientific instruments that monitor light and other electromagnetic radiation the production of sound tracks on movie films some smoke detectors. 	

Science Understanding	Possible contexts	
<p>X-ray photons can be produced when electrons that have been accelerated to high speed interact with a target. This is done in a simple X-ray tube.</p> <ul style="list-style-type: none"> Describe the purpose of the following features of a simple X-ray tube: filament, target, potential difference across the tube, evacuated tube, and a means of cooling the target. Describe the energy changes that occur during the production of X-rays, including the heat produced. <p>The three main features of the spectrum of the X-rays produced in this way are:</p> <ul style="list-style-type: none"> a continuous range of frequencies (bremsstrahlung) a maximum frequency given by $f_{\max} = \frac{e\Delta V}{h}$ where ΔV is the potential difference across the X-ray tube high-intensity peaks at particular frequencies (known as characteristic X-rays). 	<p>Investigate how the uses of X-rays are monitored and assessed, and how the risks are evaluated.</p> <p>Examples in medicine include diagnostic medicine, such as CAT or CT scans.</p> <p>Examples in industry include X-ray diffraction used in crystallography and the non-destructive analysis of art objects, X-ray microscopy of biological materials, security screening, and quality control on production lines.</p>	
<ul style="list-style-type: none"> Sketch a graph of the spectrum from an X-ray tube, showing the three main features of the spectrum. Explain the continuous range of frequencies and the maximum frequency in the spectrum of the X-rays. Explain the effect of manipulating the filament current or potential difference across the X-ray tube on an X-ray spectrum. Derive the formula for the maximum frequency, $f_{\max} = \frac{e\Delta V}{h}$. Solve problems involving the use of $f_{\max} = \frac{e\Delta V}{h}$. 	<p>Explore the uses of alternative techniques for producing or detecting X-rays, including:</p> <ul style="list-style-type: none"> synchrotron X-ray fluorescence X-ray lasers X-ray astronomy. <p>Assess the benefits and disadvantages of these in different contexts.</p>	





Science Understanding	Possible contexts	
<p>X-rays are attenuated (reduce in intensity) as they pass through matter by scattering and absorption.</p> <ul style="list-style-type: none"> • Explain the effect of the filament current on the intensity of X-rays produced by an X-ray tube. • Relate the attenuation of X-rays to the types of materials through which they pass (e.g. soft tissue, bone, metals). • Relate the penetrating power (hardness) of X-rays required to pass through a particular type of material to the energy and frequency of the X-rays. • Relate the minimum exposure time for X-ray photographs of a given hardness to the intensity of the X-rays. 		
<p>Particles exhibit wave behaviour with a wavelength (called the 'de Broglie wavelength') that depends on the momentum of the particle. The de Broglie wavelength is given by the formula $\lambda = \frac{h}{p}$, where h is Planck's constant and p is the momentum of the particles.</p> <p>The wave behaviour of particles can be demonstrated using a double-slit experiment and the Davisson–Germer experiment.</p>	<p>Discuss wave behaviour of particles and reasons why wave behaviour is only observable for small particles.</p> <p>Demonstrate simulation of two-slit interference of electrons. https://phet.colorado.edu/en/simulation/quantum-wave-interference</p> <p>Discuss the Davisson–Germer experiment and relate to transmission diffraction grating topic. https://phet.colorado.edu/en/simulation/davisson-germer</p>	
<ul style="list-style-type: none"> • Solve problems involving the use of the formula $\lambda = \frac{h}{p}$, for electrons and other particles. • Describe two-slit interference pattern produced by electrons in double-slit experiments. • Describe the Davisson–Germer experiment, in which the diffraction of electrons by the surface layers of a crystal lattice was observed. • Compare the de Broglie wavelength of electrons with the wavelength required to produce the observations of the Davisson–Germer experiment and in two-slit interference experiments. 	<p>Explore how the wave nature of electrons has led to a diverse range of contemporary applications. Examples include: electron microscope, materials research, forensics, pharmaceutical quality control.</p>	


Subtopic 3.3: Structure of the atom






Students investigate the production and features of line emission spectra from atomic gases to infer the structure of the atom, consisting of excited states with discrete energies.


Students describe and explain the visible continuous spectra emitted by hot objects and atomic absorption spectra.

Students are introduced to the phenomena of a population inversion and stimulated emission to provide a simple explanation of the operation of a laser.

Science Understanding	Possible contexts	
<p>A continuous spectrum contains a continuous range of frequencies.</p> <p>Solid, liquid, or dense gaseous objects radiate a continuous spectrum, which may extend into or beyond the visible region. The process is known as incandescence. The frequency distribution, and hence the dominant colour, depends on the temperature of the object.</p> <ul style="list-style-type: none"> Describe the changes in the spectrum of an incandescent source as the temperature of the incandescent source increases. 	<p>Demonstrate changes in the spectrum of an incandescent light globe as voltage increases.</p> 	
	<p>Investigate the relationship between temperature and frequency distribution, using a simulation. https://phet.colorado.edu/en/simulation/blackbody-spectrum</p> 	
	<p>Explore examples of the application of incandescence, such as:</p> <ul style="list-style-type: none"> red hot vs white hot white fireworks filament light bulbs. <p>Propose contexts for which the use of each is appropriate.</p> 	
<p>Atoms can be raised to excited states by heating or by bombardment with light or particles such as electrons.</p> <p>An atom is in an excited state when an electron has been raised to a higher energy level.</p> <p>The heated vapour of a pure element emits light of discrete frequencies, resulting in a line emission spectrum when the light is viewed with a spectrometer.</p> <ul style="list-style-type: none"> Describe the general characteristics of the line emission spectra of elements. Explain how the uniqueness of the spectra of elements can be used to identify the presence of an element. Explain the production of characteristic X-rays in an X-ray tube. Solve problems that require comparing spectra of different elements. 	<p>Investigate the relationship between temperature and frequency distribution, using a simulation. https://phet.colorado.edu/en/simulation/blackbody-spectrum</p> <p>Use flame tests to identify various metal atoms.</p> <p>Use spectrosopes to identify gases in a fluorescent light globe.</p> 	



Science Understanding	Possible contexts	
<p>The presence of discrete frequencies in the line emission spectra of atoms is evidence for the existence of discrete electron energy-levels in atoms.</p> <p>The different electron energy-levels can be represented on an energy-level diagram.</p> <p>When an electron makes a transition from a higher-electron energy level to a lower-electron energy level in an atom, the energy of the atom decreases and a photon is emitted.</p> <p>The energy of the emitted photon is given by the difference in the electron energy-levels of the atom. An atom is in its ground state when its electrons are in their lowest possible electron energy-level in atoms.</p> <ul style="list-style-type: none"> • Explain how the presence of discrete frequencies in line emission spectra provides evidence for the existence of states with discrete electron energy-levels in atoms. • Solve problems involving emitted photons and electron energy-levels. • Draw electron energy-level diagrams to represent the energies of different states in an atom. • Draw arrows on an electron energy-level diagram showing transitions between electron energy-levels in atoms. • Given an electron energy-level diagram, calculate the frequencies and wavelengths of lines corresponding to specified transitions. 	<p>Explore advantages and disadvantage of using vapour lamps (e.g. neon lights and sodium-vapour street lamps). When is the use of one type more appropriate than the other?</p> <p>Explore how the temperature of stars is determined from the spectrum of emitted light. How confident of their accuracy can scientists be?</p>	
<p>The line emission spectrum of atomic hydrogen consists of several series of lines.</p> <ul style="list-style-type: none"> • Draw, on an electron energy-level diagram of hydrogen, transitions corresponding to each of the series terminating at the three lowest-energy levels. • Relate the magnitude of the transitions on an electron energy-level diagram to the region in the electromagnetic spectrum of the emitted photons (ultraviolet, visible, or infrared). 	<p>Observe the emission spectrum of hydrogen using a vapour lamp and spectroscope or simulation. www.phet.colorado.edu/en/simulation/hydrogen-atom</p> <p>Discuss the energy-level diagram of hydrogen and relate to the line emission spectrum of hydrogen. Illustrate the transitions corresponding to the first three series of the hydrogen emission spectrum.</p>	


Science Understanding	Possible contexts	
<p>The ionisation energy of an atom is the minimum energy required to remove the electron from the atom in its ground state.</p> <ul style="list-style-type: none"> Determine the ionisation energy (in either joules or electron volts) of atoms using an electron energy-level diagram. 	<p>Compare and contrast the concept of ionisation in physics with the formation of metal ions.</p>	
<p>When light with a continuous spectrum is incident on a gas of an element, discrete frequencies of light are absorbed, resulting in a line absorption spectrum.</p> <p>The frequencies of the absorption lines are a subset of those in the line emission spectrum of the same element.</p> <ul style="list-style-type: none"> Describe the line absorption spectrum of an atom. On an energy-level diagram, draw transitions corresponding to the line absorption spectrum of atoms. Explain why there are no absorption lines in the visible region for hydrogen at room temperature. Account for the presence of absorption lines (Fraunhofer lines) in the Sun's spectrum. 	<p>Demonstrate line absorption spectra of various elements using simulation and relate to emission spectra and energy level diagram.</p> <p>www.phet.colorado.edu/en/simulation/hydrogen-atom</p> <p>Analyse the solar spectrum and discuss sources of Fraunhofer lines.</p>	
	<p>Explore how line absorption spectra can be used to make discoveries and reliable predictions about the composition and motion of stars.</p>	
<p>One type of fluorescence is when an electron in an atom absorbs a photon to reach a higher electron energy-level, but then reverts to its previous state by emitting two or more photons with lower energy and longer wavelength.</p> <ul style="list-style-type: none"> Explain, using an electron energy-level diagram, the production of multiple photons via fluorescence. <p>When an electron in an atom absorbs a photon and reaches a higher electron energy-level the atom is said to be in an excited state. Excited states are generally short-lived and the electron returns spontaneously to its previous electron energy-level often by emitting a series of lower-energy photons. This is known as 'spontaneous emission'.</p> <p>When a photon is incident on an electron that has been raised to a higher electron energy-level, and the energy of the photon</p>	<p>Investigate innovative applications of fluorescence, such as:</p> <ul style="list-style-type: none"> biosensors currency security features forensic science mineralogy optical brighteners gene identification defect and leak detection. <p>Consider the advantages and disadvantages of their use in different contexts.</p>	
	<p>Illustrate the process of stimulated emission on an energy-level diagram or by using a simulation.</p> <p>www.phet.colorado.edu/en/simulation/lasers</p> <p>Discuss the properties of laser light and hence the safety precautions that must be used when handling lasers.</p>	

Science Understanding	Possible contexts	
<p>corresponds to a transition to a lower electron energy-level, then the photon can stimulate an electron to transition to the lower electron energy-level. This results in two identical photons; the original photon and a second photon that results from the transition. This is known as 'stimulated emission'.</p> <ul style="list-style-type: none"> • Compare the process of stimulated emission with that of spontaneous emission. 	<p>Research the multiple lines of evidence and international communication that contributed to the development of the laser.</p> <p>Explore the ways in which lasers can be used to solve problems.</p>	
<p>Stimulated emission in gas lasers produces laser light.</p> <p>The photon emitted in stimulated emission is identical (in energy, direction, and phase) to the incident photon.</p> <ul style="list-style-type: none"> • Explain how stimulated emission can produce coherent light in a laser. <p>A population inversion is produced in a set of atoms whenever there are more atoms in a higher-energy state than in a lower-energy state. For practical systems, the higher-energy state must be metastable if a population inversion is to be produced.</p> <ul style="list-style-type: none"> • Explain the conditions required for stimulated emission to predominate over absorption when light is incident on a set of atoms. <p>The energy carried by a laser beam is concentrated in a small area and can travel efficiently over large distances, giving laser radiation a far greater potential to cause injury than light from other sources.</p> <ul style="list-style-type: none"> • Describe the useful properties of laser light (i.e. it is coherent and monochromatic, and may be of high intensity). • State the requirements for the safe handling of lasers. 	<p>Examples include:</p> <ul style="list-style-type: none"> • LADS (laser airborne depth sounder) for aircraft-based hydrographic surveying • laser cutting and welding • laser surgery • optical data storage • communication using fibre optics. <p>Research the international collaboration and communication of scientists from several countries, including Australia, in the joint project LIGO (Laser Interferometer Gravitational-Wave Observatory) to detect gravitational waves.</p>	

Subtopic 3.4: Standard Model

In this subtopic students explore theories that describe the composition of subatomic particles and how interactions between those particles can then be used to describe phenomena such as electrostatic repulsion, beta decay, and positron–electron annihilation.

Science Understanding	Possible contexts	
<p>The Standard Model suggests that there are three fundamental types of particles: gauge bosons, leptons, and quarks.</p> <p>The Standard Model identifies four fundamental forces: electromagnetic, weak nuclear, strong nuclear, and gravitational.</p> <p>Gauge bosons are particles which mediate the four fundamental forces.</p> <p>Photons are the gauge bosons for electromagnetic forces; W or Z particles are the gauge bosons for weak nuclear forces; and gluons are the gauge bosons for strong nuclear forces.</p> <p>The gauge boson for gravitational forces, the graviton, is still to be discovered.</p> <ul style="list-style-type: none"> Describe the electromagnetic, weak nuclear, and strong nuclear forces in terms of the exchange of gauge bosons. Solve problems involving the fundamental forces and gauge bosons. <p>Leptons are particles that are not affected by the strong nuclear force. There are six types of leptons – electron, electron-neutrino, muon, muon-neutrino, tau, and tau-neutrino.</p> <p>The electron, muon, and tau are negatively charged. Neutrinos do not have charge.</p> <p>Quarks are fractionally charged particles that are affected by all of the fundamental forces.</p> <p>Quarks combine to form composite particles and are never directly observed or found in isolation.</p>	<p><i>This uses the concept of the nucleus developed in Stage 1, Subtopics 6.1: The Nucleus, and 6.2: Radioactive decay.</i></p> <p>Use the online interactive from the Particle Data Group at Lawrence Berkeley National Laboratory to develop an understanding of the Standard Model. http://www.particleadventure.org/</p> <p>Use the following resource on quarks: http://neutrinoscience.blogspot.co.uk/2015/07/pentaquark-series-what-are-quarks.html</p> <p>Discuss the research using the Large Hadron Collider which has found that some particles are formed from combinations of four and five quarks: http://www.symmetrymagazine.org/article/july-2015/lhc-physicists-discover-five-quark-particle</p> <p>Discuss the adaptation of the Standard Model to include the Higgs boson, to account for the finite masses of various leptons and quarks.</p> <p>Feynman diagrams can show how gauge bosons mediate the fundamental forces.</p>	
	<p>Explore the change in understanding of the Standard Model in the light of new information using, for example, high-energy particle accelerators.</p> <p>Explore the benefits and limitations of using positron–electron annihilation in PET scanners, including for the production of gamma rays.</p> <p>Research the economic and social impacts of using the cyclotron at SAHMRI to produce radioisotopes for PET scanning.</p>	

Science Understanding	Possible contexts																						
<p>There are six types of quark, with different properties, such as mass and charge. Each quark has a charge of either $+2/3e$ or $-1/3e$.</p> <table border="1"> <thead> <tr> <th>Quark</th><th>Symbol</th><th>Charge (e)</th></tr> </thead> <tbody> <tr> <td>Up</td><td>u</td><td>$2/3$</td></tr> <tr> <td>Down</td><td>d</td><td>$-1/3$</td></tr> <tr> <td>Strange</td><td>s</td><td>$-1/3$</td></tr> <tr> <td>Charm</td><td>c</td><td>$2/3$</td></tr> <tr> <td>Top</td><td>t</td><td>$2/3$</td></tr> <tr> <td>Bottom</td><td>b</td><td>$-1/3$</td></tr> </tbody> </table> <p>Every particle has an antimatter equivalent. A key difference between a particle and its antimatter equivalent is that their charges are equal magnitude but opposite sign.</p> <ul style="list-style-type: none"> Identify which types of fundamental particles are affected by each type of fundamental force. Identify the charges of each type of fundamental particle. Describe the properties of a specified antimatter particle. Determine the charge of a specified antimatter particle. <p>All composite matter particles, such as atoms, are thought to be combinations of quarks, antiquarks, and leptons.</p> <p>Baryons are composite particles that consist of a combination of three quarks.</p> <p>Mesons are composite particles that consist of a combination of one quark and one antiquark.</p> <ul style="list-style-type: none"> Describe how protons, neutrons, and other baryons consists of different combinations of quarks. Determine the charge of a baryon, given its quark composition. Describe how pions and other mesons consist of different combinations of quarks and antiquarks. Determine the charge of a meson, given its quark-antiquark composition. <p>Each particle is assigned a lepton number and a baryon number.</p> <p>Lepton numbers can be one of three types:</p> <ul style="list-style-type: none"> – electronic lepton number, L_e – muonic lepton number, L_μ – tauonic lepton number, L_τ 	Quark	Symbol	Charge (e)	Up	u	$2/3$	Down	d	$-1/3$	Strange	s	$-1/3$	Charm	c	$2/3$	Top	t	$2/3$	Bottom	b	$-1/3$	<p>Explore how beta minus decay involves the conversion of a neutron to a proton accompanied by the production of an electron and an antineutrino.</p> <p>Explore how beta plus decay involves the conversion of a proton to a neutron, accompanied by the production of an electron and an antineutrino.</p> <p>Explore how beta decay can be explained in terms of the conversion of quarks.</p>	
Quark	Symbol	Charge (e)																					
Up	u	$2/3$																					
Down	d	$-1/3$																					
Strange	s	$-1/3$																					
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Bottom	b	$-1/3$																					

Science Understanding	Possible contexts	
<p>The lepton number, regardless of type, for a lepton is 1. Antileptons have a lepton number of -1. All other particles have a lepton number of 0.</p> <p>The baryon number of a quark is $1/3$. Baryons have a baryon number of 1. Antiquarks have a baryon number of $-1/3$. Antibaryons have a baryon number of -1.</p> <p>All other fundamental particles have a baryon number of 0.</p>		
<p>The laws of the conservation of baryon number, charge, and lepton number determine the types of reactions that can occur between particles.</p> <ul style="list-style-type: none"> • Use the conservation laws to determine the baryon number, lepton number, and charge of particles in reactions. • Given a reaction between particles, demonstrate that baryon number, lepton number, and charge are conserved. <p>When a particle and its antiparticle collide, they annihilate, releasing energy according to the mass–energy equivalence formula:</p> $E = \Delta mc^2.$ <ul style="list-style-type: none"> • Use the mass–energy equivalence relation to determine the energy released when a particle and antiparticle annihilate. 		

ASSESSMENT SCOPE AND REQUIREMENTS

All Stage 2 subjects have a school assessment component and an external assessment component.

EVIDENCE OF LEARNING

The following assessment types enable students to demonstrate their learning in Stage 2 Physics:

School assessment (70%)

- Assessment Type 1: Investigations Folio (30%)
- Assessment Type 2: Skills and Applications Tasks (40%)

External assessment (30%)

- Assessment Type 3: Examination (30%).

Students provide evidence of their learning through eight assessments, including the external assessment component. Students complete:

- at least two practical investigations
- one investigation with a focus on science as a human endeavour
- at least three skills and applications tasks
- one examination.

At least one investigation or skills and applications task should involve collaborative work.

ASSESSMENT DESIGN CRITERIA

The assessment design criteria are based on the learning requirements and are used by:

- teachers to clarify for the student what they need to learn
- teachers and assessors to design opportunities for the student to provide evidence of their learning at the highest possible level of achievement.

The assessment design criteria consist of specific features that:

- students should demonstrate in their learning
- teachers and assessors look for as evidence that students have met the learning requirements.

For this subject, the assessment design criteria are:

- investigation, analysis, and evaluation
- knowledge and application.

The specific features of these criteria are described below.

The set of assessments, as a whole, must give students opportunities to demonstrate each of the specific features by the completion of study of the subject.

Investigation, Analysis, and Evaluation

The specific features are as follows:

- IAE1 Deconstruction of a problem and design of a physics investigation.
- IAE2 Obtaining, recording, and representation of data, using appropriate conventions and formats.
- IAE3 Analysis and interpretation of data and other evidence to formulate and justify conclusions.
- IAE4 Evaluation of procedures and their effect on data.

Knowledge and Application

The specific features are as follows:

- KA1 Demonstration of knowledge and understanding of physics concepts.
- KA2 Application of physics concepts in new and familiar contexts.
- KA3 Exploration and understanding of the interaction between science and society.
- KA4 Communication of knowledge and understanding of physics concepts and information, using appropriate terms, conventions and representations.

SCHOOL ASSESSMENT

Assessment Type 1: Investigations Folio (30%)

Students undertake at least two practical investigations and one investigation with a focus on science as a human endeavour. Students may undertake more than two practical investigations within the maximum number of assessments allowed in the school assessment component. They inquire into aspects of physics through practical discovery and data analysis, and/or by selecting, analysing, and interpreting information.

Practical Investigations

As students design and safely carry out investigations, they demonstrate their science inquiry skills by:

- deconstructing a problem to determine the most appropriate method for investigation
- formulating investigable questions and hypotheses
- selecting and using appropriate equipment, apparatus, and techniques
- identifying variables
- collecting, representing, analysing, and interpreting data

- evaluating procedures and considering their impact on results
- drawing conclusions
- communicating knowledge and understanding of concepts.

As a set, practical investigations should enable students to:

- work both individually or collaboratively
- investigate a question or hypothesis for which the outcome is uncertain.
- investigate a question or hypothesis linked to one of the topics in Stage 2 Physics
- individually deconstruct a problem to design their own method and justify their plan of action.

For each investigation, students present an individual report.

Evidence of deconstruction (where applicable) should outline the deconstruction process, the method designed as most appropriate, and a justification of the plan of action, to a maximum of 4 sides of an A4 page. This evidence must be attached to the practical report.

Suggested formats for this evidence include flow charts, concept maps, tables, or notes.

In order to manage the implementation of an investigation efficiently, students could individually design investigations and then conduct one of these as a group, or design hypothetical investigations at the end of a practical activity.

A practical report must include:

- introduction with relevant physics concepts, and either a hypothesis and variables, or an investigable question
- materials/apparatus
- the method that was implemented
- identification and management of safety and/or ethical risks
- results, including table(s) and/or graph(s)
- analysis of results, including identifying trends and linking results to concepts
- evaluation of procedures and their effect on data, and identifying sources of uncertainty
- conclusion, with justification.

The report should be a maximum of 1500 words if written, or a maximum of 10 minutes for an oral presentation, or the equivalent in multimodal form.

Only the following sections of the report are included in the word count:

- introduction
- analysis of results
- evaluation of procedures
- conclusion and justification.

Suggested formats for presentation of a practical investigation report include:

- a written report
- an oral presentation
- a multimodal product.

Science as a Human Endeavour Investigation

Students investigate a contemporary example of how science interacts with society. This may focus on one or more of the key concepts of science as a human endeavour described on pages 11 and 12, and may draw on a context suggested in the topics or relate to a new context.

Students select and explore a recent discovery, innovation, issue, or advance linked to one of the topics in Stage 2 Physics. They analyse and synthesise information from different sources to explain the science relevant to the focus of their investigation, show its connections to science as a human endeavour, and develop a conclusion.

Possible starting points for the investigation could include, for example:

- the announcement of a discovery in the field of physics
- an expert's point of view on a controversial innovation
- a TED talk based on a development in physics
- an article from a scientific publication (e.g. *Cosmos*)
- public concern about an issue that has environmental, social, economic, or political implications
- changes in government funding for physics-related purposes, e.g. for scientific research into decommissioned satellites and spent rocket stages, various forms of medical imaging, quantum computers and extremely high data transfer, ring laser guidance systems and their application for accurate aircraft navigation, use of nuclear isotopes for industrial or medical applications, monitoring changes in global temperature
- 'blue sky' research leading to new technologies.

Based on their investigation, students prepare a scientific report, which must include the use of scientific terminology and:

- an introduction to identify the focus of the investigation and the key concept(s) of science as a human endeavour that it links to
- relevant physics concepts or background
- an explanation of how the focus of the investigation illustrates the interaction between science and society, including a discussion of the potential impact of the focus of the investigation, e.g. further development, effect on quality of life, environmental implications, economic impact, intrinsic interest
- a conclusion
- citations and referencing.

The scientific report should be a maximum of 1500 words if written, or a maximum of 10 minutes for an oral presentation, or the equivalent in multimodal form.

This report could take the form of, for example:

- an article for a scientific publication
- an oral or multimodal scientific presentation.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

Assessment Type 2: Skills and Applications Tasks (40%)

Students undertake at least three skills and applications tasks. Students may undertake more than three skills and applications tasks within the maximum number of assessments allowed in the school assessment component, but at least three should be under the direct supervision of the teacher. The supervised setting should be appropriate to the task. Each supervised task should be a maximum of 90 minutes of class time, excluding reading time.

Skills and applications tasks allow students to provide evidence of their learning in tasks that may:

- be applied, analytical, and/or interpretative
- pose problems in new and familiar contexts
- involve individual or collaborative assessments, depending on task design.

A skills and applications task may involve, for example:

- solving problems
- designing an investigation to test a hypothesis or investigable question
- considering different scenarios in which to apply knowledge and understanding
- graphing, tabulating, and/or analysing data
- evaluating procedures and identifying their limitations
- formulating and justifying conclusions
- representing information diagrammatically or graphically
- using physics terms, conventions, and notations.

As a set, skills and applications tasks should be designed to enable students to apply their science inquiry skills, demonstrate knowledge and understanding of key physics concepts and learning, and explain connections with science as a human endeavour. Problems and scenarios should be set in a relevant context, which may be practical, social, or environmental.

Skills and applications tasks may include, for example:

- developing simulations
- practical and/or graphical skills
- a multimodal product
- an oral presentation
- participation in a debate
- an extended response
- responses to short-answer questions
- a response to science in the media.

For this assessment type, students provide evidence of their learning in relation to the following assessment design criteria:

- investigation, analysis, and evaluation
- knowledge and application.

EXTERNAL ASSESSMENT

Assessment Type 3: Examination (30%)

Students undertake a 130-minute examination.

Stage 2 science inquiry skills and science understanding from all topics may be assessed.

Questions:

- will be of different types
- may require students to show an understanding of science as a human endeavour
- may require students to apply their science understanding from more than one topic.

For the examination, students are given a sheet containing symbols of common quantities, the magnitude of physical constants, some formulae, and standard SI prefixes.

All specific features of the assessment design criteria for this subject may be assessed in the external examination.

PERFORMANCE STANDARDS

The performance standards describe five levels of achievement, A to E.

Each level of achievement describes the knowledge, skills, and understanding that teachers and assessors refer to in deciding how well students have demonstrated their learning on the basis of the evidence provided.

During the teaching and learning program the teacher gives students feedback on their learning, with reference to the performance standards.

At the student's completion of study of each school assessment type, the teacher makes a decision about the quality of the student's learning by:

- referring to the performance standards
- assigning a grade between A+ and E– for the assessment type.

The student's school assessment and external assessment are combined for a final result, which is reported as a grade between A+ and E–.

Performance Standards for Stage 2 Physics

Investigation, Analysis and Evaluation		Knowledge and Application
A	<p>Critically deconstructs a problem and designs a logical, coherent, and detailed physics investigation.</p> <p>Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively.</p> <p>Systematically analyses and interprets data and evidence to formulate logical conclusions with detailed justification.</p> <p>Critically and logically evaluates procedures and their effect on data.</p>	<p>Demonstrates deep and broad knowledge and understanding of a range of physics concepts.</p> <p>Applies physics concepts highly effectively in new and familiar contexts.</p> <p>Critically explores and understands in depth the interaction between science and society.</p> <p>Communicates knowledge and understanding of physics coherently, with highly effective use of appropriate terms, conventions, and representations.</p>
B	<p>Logically deconstructs a problem and designs a well-considered and clear physics investigation.</p> <p>Obtains, records, and represents data, using appropriate conventions and formats mostly accurately and effectively.</p> <p>Logically analyses and interprets data and evidence to formulate suitable conclusions with reasonable justification.</p> <p>Logically evaluates procedures and their effect on data.</p>	<p>Demonstrates some depth and breadth of knowledge and understanding of a range of physics concepts.</p> <p>Applies physics concepts mostly effectively in new and familiar contexts.</p> <p>Logically explores and understands in some depth the interaction between science and society.</p> <p>Communicates knowledge and understanding of physics mostly coherently, with effective use of appropriate terms, conventions, and representations.</p>
C	<p>Deconstructs a problem and designs a considered and generally clear physics investigation.</p> <p>Obtains, records, and represents data, using generally appropriate conventions and formats, with some errors but generally accurately and effectively.</p> <p>Undertakes some analysis and interpretation of data and evidence to formulate generally appropriate conclusions with some justification.</p> <p>Evaluates procedures and some of their effect on data.</p>	<p>Demonstrates knowledge and understanding of a general range of physics concepts.</p> <p>Applies physics concepts generally effectively in new or familiar contexts.</p> <p>Explores and understands aspects of the interaction between science and society.</p> <p>Communicates knowledge and understanding of physics generally effectively, using some appropriate terms, conventions, and representations.</p>
D	<p>Prepares a basic deconstruction of a problem and an outline of a physics investigation.</p> <p>Obtains, records, and represents data, using conventions and formats inconsistently, with occasional accuracy and effectiveness.</p> <p>Describes data and undertakes some basic interpretation to formulate a basic conclusion.</p> <p>Attempts to evaluate procedures or suggest an effect on data.</p>	<p>Demonstrates some basic knowledge and partial understanding of physics concepts.</p> <p>Applies some physics concepts in familiar contexts.</p> <p>Partially explores and recognises aspects of the interaction between science and society.</p> <p>Communicates basic physics information, using some appropriate terms, conventions, and/or representations.</p>
E	<p>Attempts a simple deconstruction of a problem and a procedure for a physics investigation.</p> <p>Attempts to record and represent some data, with limited accuracy or effectiveness.</p> <p>Attempts to describe results and/or interpret data to formulate a basic conclusion.</p> <p>Acknowledges that procedures affect data.</p>	<p>Demonstrates limited recognition and awareness of physics concepts.</p> <p>Attempts to apply physics concepts in familiar contexts.</p> <p>Attempts to explore and identify an aspect of the interaction between science and society.</p> <p>Attempts to communicate information about physics.</p>

ASSESSMENT INTEGRITY

The SACE Assuring Assessment Integrity Policy outlines the principles and processes that teachers and assessors follow to assure the integrity of student assessments. This policy is available on the SACE website (www.sace.sa.edu.au) as part of the SACE Policy Framework.

The SACE Board uses a range of quality assurance processes so that the grades awarded for student achievement, in both the school assessment and the external assessment, are applied consistently and fairly against the performance standards for a subject, and are comparable across all schools.

Information and guidelines on quality assurance in assessment at Stage 2 are available on the SACE website (www.sace.sa.edu.au).

SUPPORT MATERIALS

SUBJECT-SPECIFIC ADVICE

Online support materials are provided for each subject and updated regularly on the SACE website (www.sace.sa.edu.au). Examples of support materials are sample learning and assessment plans, annotated assessment tasks, annotated student responses, and recommended resource materials.

ADVICE ON ETHICAL STUDY AND RESEARCH

Advice for students and teachers on ethical study and research practices is available in the guidelines on the ethical conduct of research in the SACE on the SACE website (www.sace.sa.edu.au).