Physics 2025 v1.2

General senior syllabus

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Queensland Government

Queensland Curriculum & Assessment Authority

For all Queensland schools

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Contents

Queensland syllabuses for senior subjects

In Queensland, a syllabus for a senior subject is an official ‘map’ of a senior school subject. A syllabus’s function is to support schools in delivering the Queensland Certificate of Education (QCE) system through high-quality and high-equity curriculum and assessment.

Syllabuses are based on design principles developed from independent international research about how excellence and equity are promoted in the documents teachers use to develop and enliven the curriculum.

Syllabuses for senior subjects build on student learning in the Prep to Year 10 Australian Curriculum and include General, General (Extension), Senior External Examination (SEE), Applied, Applied (Essential) and Short Course syllabuses.

More information about syllabuses for senior subjects is available at www.qcaa.qld.edu.au/senior/senior-subjects and in the ‘Queensland curriculum’ section of the *QCE and QCIA policy and procedures handbook*.

Teaching, learning and assessment resources will support the implementation of a syllabus for a senior subject. More information about professional resources for senior syllabuses is available on the QCAA website and via the QCAA Portal.

Course overview

Rationale

At the core of all scientific endeavour is the inquiry into the nature of the universe. Science uses a systematic way of thinking, involving creative and critical reasoning, in order to acquire better and more reliable knowledge. Scientists recognise that knowledge is not fixed, but is fallible and open to challenge. As such, scientific endeavour is never conducted in isolation, but builds on and challenges an existing body of knowledge in the pursuit of more reliable knowledge. This collaborative process, whereby new knowledge is gained, is essential to the cooperative advancement of science, technology, health and society in the 21st century.

Tertiary study in any field will be aided by the transferable skills developed in this senior Science subject. It is expected that an appreciation of, and respect for, evidence-based conclusions and the processes required to gather, scrutinise and use evidence will be carried forward into all aspects of life beyond the classroom.

The purpose of senior Science subjects in Queensland is to introduce students to a scientific discipline. Students will be required to learn and apply aspects of the knowledge and skill of the discipline (thinking, experimentation, problem-solving and research skills), understand how it works and how it may impact society.

Upon completion of the course, students will have an appreciation for a body of scientific knowledge and the process that is undertaken to acquire this knowledge. They will be able to distinguish between claims and evidence, opinion and fact, and conjecture and conclusions.

In each of the senior Science subjects, students will develop:

- a deep understanding of a core body of discipline knowledge
- aspects of the skills used by scientists to develop new knowledge, as well as the opportunity to refine these skills through practical activities
- the ability to coordinate their understandings of the knowledge and skills associated with the discipline to refine experiments, verify known scientific relationships, explain phenomena with justification and evaluate claims by finding evidence to support or refute the claims.

Physics provides opportunities for students to engage with the classical and modern understandings of the universe. In Unit 1, students learn about the fundamental concepts of thermodynamics, electricity and nuclear processes. In Unit 2, students learn about the concepts and theories that predict and describe the linear motion of objects. Further, they will explore how scientists explain some phenomena using an understanding of waves. In Unit 3, students engage with the concept of gravitational and electromagnetic fields, and the relevant forces associated with them. Finally, in Unit 4, students study modern physics theories and models that, despite being counterintuitive, are fundamental to our understanding of many common observable phenomena.

Students will learn valuable skills required for the scientific investigation of questions. In addition, they will become citizens who are better informed about the world around them, and who have the critical skills to evaluate and make evidence-based decisions about current scientific issues.

Physics aims to develop students':

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

Syllabus objectives

The syllabus objectives outline what students have the opportunity to learn.

1. **Describe ideas and findings.**

   Students use scientific representations and language in appropriate genres to give a detailed account of scientific phenomena, concepts, theories, models and systems.

2. **Apply understanding.**

   Students use scientific concepts, theories, models and systems within their limitations. They use algebraic, visual and graphical representations of scientific relationships and data to determine unknown scientific quantities or features. They explain phenomena, concepts, theories, models, systems and modifications to methodologies.

3. **Analyse data.**

   Students consider scientific information from primary and secondary sources to identify trends, patterns, relationships, limitations and uncertainty. In qualitative data, they identify the essential elements, features or components. In quantitative data, they use mathematical processes and algorithms. They identify data to support ideas, conclusions or decisions.

4. **Interpret evidence.**

   Students use their understanding of scientific concepts, theories, models and systems and their limitations to draw conclusions and develop scientific arguments. They deduce, extrapolate, infer, justify and make predictions based on their analysis of data.

5. **Evaluate conclusions, claims and processes.**

   Students critically reflect on the available evidence and make judgments about its application to research questions. They extrapolate findings to support or refute claims. They use the quality of the evidence to evaluate the validity and reliability of inquiry processes and suggest improvements and extensions for further investigation.

6. **Investigate phenomena.**

   Students develop rationales and research questions for experiments and investigations. They modify methodologies to collect primary data and select secondary sources. They manage risks, environmental and ethical issues and acknowledge sources of information.

Designing a course of study in Physics

Syllabuses are designed for teachers to make professional decisions to tailor curriculum and assessment design and delivery to suit their school context and the goals, aspirations and abilities of their students within the parameters of Queensland's senior phase of learning.

The syllabus is used by teachers to develop curriculum for their school context. The term *course of study* describes the unique curriculum and assessment that students engage with in each school context. A course of study is the product of a series of decisions made by a school to select, organise and contextualise subject matter, integrate complementary and important learning, and create assessment tasks in accordance with syllabus specifications.

It is encouraged that, where possible, a course of study is designed such that teaching, learning and assessment activities are integrated and enlivened in an authentic setting.

Course structure

Physics is a General senior syllabus. It contains four QCAA-developed units from which schools develop their course of study.

Each unit has been developed with a notional time of 55 hours of teaching and learning, including assessment.

Students should complete Unit 1 and Unit 2 before beginning Units 3 and 4. Units 3 and 4 are studied as a pair.

More information about the requirements for administering senior syllabuses is available in the 'Queensland curriculum' section of the *QCE and QCIA policy and procedures handbook*.

Curriculum

Senior syllabuses set out only what is essential while being flexible so teachers can make curriculum decisions to suit their students, school context, resources and expertise.

Within the requirements set out in this syllabus and the *QCE and QCIA policy and procedures handbook*, schools have autonomy to decide:

- how and when subject matter is delivered
- how, when and why learning experiences are developed, and the context in which learning occurs
- how opportunities are provided in the course of study for explicit and integrated teaching and learning of complementary skills.

These decisions allow teachers to develop a course of study that is rich, engaging and relevant for their students.

Assessment

Senior syllabuses set out only what is essential while being flexible so teachers can make assessment decisions to suit their students, school context, resources and expertise.

General senior syllabuses contain assessment specifications and conditions for the assessment instruments that must be implemented with Units 3 and 4. These specifications and conditions ensure comparability, equity and validity in assessment.

Within the requirements set out in this syllabus and the *QCE and QCIA policy and procedures handbook*, schools have autonomy to decide:

- specific assessment task details
- assessment contexts to suit available resources
- how the assessment task will be integrated with teaching and learning activities
- how authentic the task will be.

In Unit 1 and Unit 2, schools:

- develop at least two but no more than four assessments
- complete at least one assessment for each unit
- ensure that each unit objective is assessed at least once.

In Units 3 and 4, schools develop three assessments using the assessment specifications and conditions provided in the syllabus.

More information about assessment in senior syllabuses is available in ‘The assessment system’ section of the *QCE and QCIA policy and procedures handbook*.

Subject matter

Each unit contains a unit description, unit objectives and subject matter. Subject matter is the body of information, mental procedures and psychomotor procedures (see Marzano & Kendall 2007, 2008) that are necessary for students’ learning and engagement with the subject. Subject matter itself is not the specification of learning experiences but provides the basis for the design of student learning experiences.

Subject matter has a direct relationship with the unit objectives and provides statements of learning that have been constructed in a similar way to objectives.

Aboriginal perspectives and Torres Strait Islander perspectives

The QCAA is committed to reconciliation. As part of its commitment, the QCAA affirms that:

- Aboriginal peoples and Torres Strait Islander peoples are the first Australians, and have the oldest living cultures in human history
- Aboriginal peoples and Torres Strait Islander peoples have strong cultural traditions and speak diverse languages and dialects, other than Standard Australian English
- teaching and learning in Queensland schools should provide opportunities for students to deepen their knowledge of Australia by engaging with the perspectives of Aboriginal peoples and Torres Strait Islander peoples
- positive outcomes for Aboriginal students and Torres Strait Islander students are supported by successfully embedding Aboriginal perspectives and Torres Strait Islander perspectives across planning, teaching and assessing student achievement.

Guidelines about Aboriginal perspectives and Torres Strait Islander perspectives and resources for teaching are available at www.qcaa.qld.edu.au/k-12-policies/aboriginal-torres-strait-islander-perspectives.

Where appropriate, Aboriginal perspectives and Torres Strait Islander perspectives have been embedded in the subject matter.

Complementary skills

Opportunities for the development of complementary skills have been embedded throughout subject matter. These skills, which overlap and interact with syllabus subject matter, are derived from current education, industry and community expectations and encompass the knowledge, skills, capabilities, behaviours and dispositions that will help students live and work successfully in the 21st century.

These complementary skills are:

- literacy — the knowledge, skills, behaviours and dispositions about language and texts essential for understanding and conveying English language content
- numeracy — the knowledge, skills, behaviours and dispositions that students need to use mathematics in a wide range of situations, to recognise and understand the role of mathematics in the world, and to develop the dispositions and capacities to use mathematical knowledge and skills purposefully
- 21st century skills — the attributes and skills students need to prepare them for higher education, work, and engagement in a complex and rapidly changing world. These skills include critical thinking, creative thinking, communication, collaboration and teamwork, personal and social skills, and digital literacy. The explanations of associated skills are available at www.qcaa.qld.edu.au/senior/senior-subjects/general-subjects/21st-century-skills.

It is expected that aspects of literacy, numeracy and 21st century skills will be developed by engaging in the learning outlined in this syllabus. Teachers may choose to create additional explicit and intentional opportunities for the development of these skills as they design the course of study.

Additional subject-specific information

Additional subject-specific information has been included to support and inform the development of a course of study.

Science understanding

The science understanding subject matter in each unit develops students' understanding of the key concepts, models and theories that underpin the subject, and of the strengths and limitations of different models and theories for explaining and predicting complex phenomena. It uses cognitions from Objectives 1–4.

The science understanding subject matter from Units 3 and 4 will be assessed by the external assessment.

Science as a human endeavour (SHE)

Each Queensland senior science subject requires students to learn and apply aspects of the knowledge and skill of the discipline. However, it is recognised that students should also develop an appreciation for the *nature* and *development* of science, and its *use* and *influence* on society.

While this appreciation is not directly assessed, the syllabus provides guidance as to where it may be developed. Importantly, this guidance draws students' attention to the way in which science operates, both in relation to the development of understanding and explanations about the world and to its influence on society.

Students should become familiar with the following SHE concepts:

- Science is a global enterprise that relies on clear communication, international conventions, peer review and reproducibility.
- Development of complex models and/or theories often requires a wide range of evidence from multiple individuals and across disciplines.
- Advances in science understanding in one field can influence other areas of science, technology and engineering.
- The use and acceptance of scientific knowledge is influenced by social, economic, cultural and ethical contexts.
- The use of scientific knowledge may have beneficial and/or harmful and/or unintended consequences.
- Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions.
- Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability.
- ICT and other technologies have dramatically increased the size, accuracy and geographic and temporal scope of datasets with which scientists work.
- Models and theories are contested and refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power.
- Scientific knowledge can be used to inform the monitoring, assessment and evaluation of risk.
- Science can be limited in its ability to provide definitive answers to public debate; there may be insufficient reliable data available, or interpretation of the data may be open to question.
- International collaboration is often required when investing in large-scale science projects or addressing issues for the Asia–Pacific region.

To support the development of these concepts, this syllabus identifies SHE subject matter in each unit. This highlights opportunities for teachers to contextualise the associated science understanding and science inquiry subject matter and provides stimulus for the development of claims and research questions for investigation.

Additional opportunities include:

- practicals provide opportunities for students to witness the *nature* of science
- the student experiment provides opportunity for students to experience how the *development* of new science knowledge is built upon existing knowledge
- the research investigation provides opportunity for students to appreciate the *use* and *influence* of scientific evidence to make decisions or to contribute to public debate about a claim.

Science inquiry

Defining *inquiry* in science education

In order to support the school's task of aligning their chosen pedagogical framework with the curriculum and assessment expectations outlined in this syllabus, some guidance has been provided in the form of clarification of the use of the term *inquiry* and the articulation of a framework to describe the process of inquiry. The purpose of this guidance is to prevent misunderstandings and problematic conflations and their subsequent negative impact on student learning. As Abrams, Southerland and Silva (2008, p. xv) stated in their book, *Inquiry in the Classroom: Realities and opportunities*:

> Inquiry in the classroom can be conceived as a complex set of ideas, beliefs, skills, and/or pedagogies. It is evident that attempting to select a singular definition of inquiry may be an insurmountable and fruitless task. Any single definition of inquiry in the classroom would necessarily reflect the thinking of a particular school of thought, at a particular moment in time, or a particular goal, and such a singular definition may serve to limit legitimate and necessary components of science learning. **However, operating without a firm understanding of the various forms of inquiry leaves science educators often 'talking past' one another, and often results in very muddled attempts in the classroom** [emphasis added].

Uses of the term *inquiry*

Common phrases involving the term *inquiry* have been listed below:

- science inquiry
- science inquiry skills
- the inquiry process
- inquiry-based learning.

This syllabus refers to the first three uses listed above. The first, *science inquiry*, defines the practical work of a scientist (Harlen 2013). The second, *science inquiry skills*, refers to the skills required to do the work of a scientist (Harlen 2013). The third, *the inquiry process*, is a framework that can be used to describe the process of asking a question and then answering it.

The final phrase, *inquiry-based learning*, refers to a variety of teaching and learning strategies an educator may choose to use within their school's pedagogical framework. Although a school may choose to adopt an inquiry-based pedagogy, this syllabus is *not* intended to endorse or recommend an inquiry-based learning approach.

Framework to describe the inquiry process

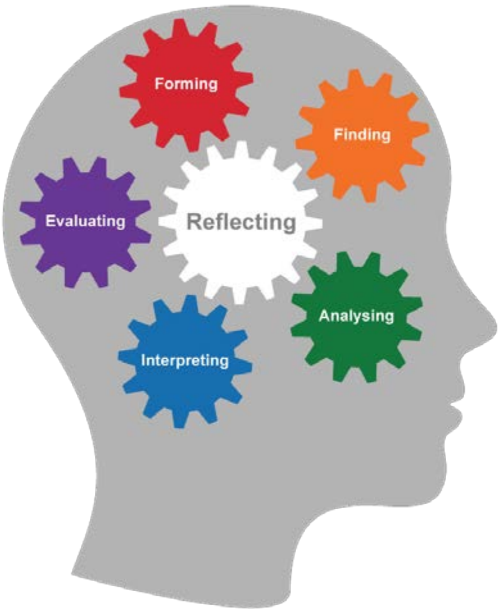
In order to support student engagement in activities involving inquiry, it is useful to establish a common language or framework to distinguish between stages of the process.

The stages involved in any inquiry are:

- forming and describing the inquiry activity
- finding valid and reliable evidence for the inquiry activity
- analysing the evidence collected
- interpreting the evidence selected
- evaluating the conclusions, processes or claims.

This framework uses reflection as the connection between, and driver of, all the stages. The progression through the inquiry process requires reflection on the decisions made and any new information that has emerged during the process to inform the next stage. Each stage of the inquiry process is worthy of reflection, the result of which may be the revision of previous stages (Marzano & Kendall 2007).

Figure 1: Stages of inquiry process



Science inquiry and science inquiry skills

Science inquiry involves identifying and posing questions and working to answer them. It is concerned with evaluating claims, investigating ideas, solving problems, reasoning, drawing valid conclusions and developing evidence-based arguments. It can easily be summarised as the 'work of a scientist' (Hackling 2005).

Within this syllabus, it is expected that students will engage in *aspects* of the work of a scientist by engaging in scientific inquiry (Tytler 2007). This expectation can be seen, for example, by the inclusion of practicals and investigations in the subject matter, and in the internal assessments for Units 3 and 4.

Science inquiry skills are the skills required to do the work of a scientist. They include writing research questions, planning, conducting, recording information, and reflecting on investigations; processing, analysing and interpreting evidence; evaluating conclusions, processes and claims; and communicating findings (ACARA 2015).

It is expected that students are explicitly taught science inquiry skills (Krajcik et al 2000), a number of which are outlined throughout the syllabus. Some science inquiry skills will be used to complete the listed practicals and investigations. The selection, application and coordination of science inquiry skills will be required in the student experiment and research investigation.

It is the prerogative of the educator to determine how listed practicals and investigations are used as opportunities to:

- develop, rehearse and refine science inquiry skills
- engage students in scaffolded or open-ended science inquiry tasks
- formatively assess science inquiry skills.

Science inquiry skills

Throughout the course of study, students will:

- identify, research and construct questions for investigation
- propose hypotheses and/or predict possible outcomes
- design investigations, including the procedure/s to be followed, the materials required, and the type and amount of primary and/or secondary data required to obtain valid and reliable evidence, e.g.
  - consider replicates, number of data points, and quality of sources
  - identify the types of errors, extraneous variables or confounding factors that are likely to influence results and implement strategies to minimise systematic and random error
- identify and implement strategies to manage risks, ethics and environmental impact, e.g.
  - cultural guidelines, protocols for working with the knowledges of First Nations peoples
  - workplace health and safety guidelines
  - standard operating procedures
  - acknowledgment of sources and referencing
- use appropriate equipment, techniques, procedures and sources to systematically and safely collect primary and secondary data, e.g.
  - laboratory and field techniques: measurement, and equipment calibration
  - ICTs, scientific texts, databases, online sources

- use scientific language and representations to systematically record information, observations, data and measurement error, e.g.
  - symbols, units and prefixes
  - tables, graphs and diagrams
  - indicators of measurement uncertainty and state measurement uncertainties as a range (±) to an appropriate precision, e.g. when adding or subtracting, the final answer should be given to the least number of decimal places, when multiplying or dividing, the final answer should be given to the least number of significant figures
  - logbooks
- translate information between graphical, numerical and/or algebraic forms
  - units and measurement conversions
  - symbols and notation
- use mathematical techniques to summarise data in a way that allows for identification of relevant trends, patterns, relationships, limitations and uncertainty, e.g.
  - mean
  - gradient analysis
  - scatterplots (with maximum and minimum trendlines and R^2)
  - propagate random error in data processing to show the impact of measurement uncertainties on the final result
  - apply simple treatment of error analysis, e.g. for functions such as addition and subtraction, absolute uncertainties should be added, for multiplication, division and powers, percentage uncertainties should be added
  - calculate the measurement uncertainties in processed data, including the use of absolute uncertainties of the mean (Formula: $\Delta\bar{x} = \pm\frac{(x_{max}-x_{min})}{2}$) and percentage uncertainties (Formula: $\text{percentage uncertainty (\%)} = \frac{\text{absolute uncertainty}}{\text{measurement}} \times 100\%$)
  - calculate the percentage error, when the experimental result can be compared with a theoretical or accepted result (value)
    (Formula: $\text{percentage error (\%)} = \left|\frac{\text{measured value} - \text{true value}}{\text{true value}}\right| \times 100\%$)
  - discriminate between absolute uncertainty and percentage error
- select and construct appropriate representations to present data and communicate findings, e.g.
  - summary tables
  - scatterplots (with maximum and minimum trendlines and R^2)
  - scientific drawings
  - apply appropriate graphical representations to analyse data and draw conclusions
- analyse data to identify trends, patterns and relationships; recognising error, uncertainty and limitations of evidence
- interpret graphs in terms of the relationship between dependent and independent variables; draw and interpret best-fit lines or curves through data points, including evaluating when it can and cannot be considered as a linear function

- discriminate between precision and accuracy
  - identify that all measurements have limits to their precision and accuracy that must be considered when evaluating experimental results
  - identify that quantitative data obtained from measurements is associated with random error/measurement uncertainties
- select, synthesise and use evidence to construct scientific arguments and draw conclusions
- extrapolate findings to determine unknown values, predict outcomes and evaluate claims
- use data and reasoning to discuss and evaluate the validity and reliability of evidence, e.g.
  - discuss ways in which measurement error, instrumental uncertainty, the nature of the methodology or other factors influence uncertainty and limitations in the data
  - evaluate information sources and compare ideas, information and opinions presented within and between texts, considering aspects such as acceptance, bias, status, appropriateness and reasonableness
  - compare findings to theoretical models or expected values
  - discriminate between validity and reliability
- suggest improvements and extensions to minimise uncertainty, address limitations and improve the overall quality of evidence, e.g.
  - analyse the impact of random error/measurement uncertainties and systematic errors in experimental work and determine how these errors/measurement uncertainties can be reduced
  - discriminate between random and systematic errors
  - identify that experimental design and procedure usually leads to systematic errors in measurement, which causes a deviation in a direction and that repeated trials and measurements will reduce random error but not systematic error
- communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes
- acknowledge sources of information and use standard scientific referencing conventions.
- appreciate the role of peer review in scientific research.

Science inquiry subject matter uses cognitions from across all objectives, and is primarily assessed through the internal assessments for Units 3 and 4. To support the development of these science inquiry skills, this syllabus identifies suggested practicals and investigations for each unit. These highlight opportunities for students to directly experience the associated science understanding subject matter and provide stimulus for student experiments and research investigations.

Safety and ethics

Workplace health and safety

Physics is designed to expose students to the practical components of science through practical experiences in the laboratory and the field. These experiences expose students to a variety of hazards, from biological and poisonous substances to injury from equipment. Besides a teacher's duty of care that derives from the *Education (General Provisions) Act 2006*, there are other legislative and regulatory requirements, for example the *Work Health and Safety Act 2011*, that will influence the nature and extent of practical work.

All practical work must be organised with student safety in mind. The *Department of Education and Training (DET) Policy and Procedure Register* (https://ppr.qed.qld.gov.au) provides guidance about current science safety protocols.

It is the responsibility of all schools to ensure that their practices meet current legislation requirements.

Strategies for retaining and recalling information for assessment

The following practices[1] can support preparation for senior assessment in Physics.

The spacing effect

The spacing effect draws on research about forgetting and learning curves. By recalling and revisiting information at intervals, rather than at the end of a study cycle, students remember a greater percentage of the information with a higher level of accuracy. Exposing students to information and materials numerous times over multiple spaced intervals solidifies long-term memory, positively affecting retention and recall.

Teachers should plan teaching and learning sequences that allow time to revisit previously taught information and skills at several intervals. These repeated learning opportunities also provide opportunities for teachers to provide formative feedback to students.

The retrieval effect

The retrieval effect helps students to practise remembering through quick, regular, low-stakes questioning or quizzes that exercise their memories and develop their ability to engage in the deliberate act of recalling information. This has been shown to be more effective at developing long-term memories than activities that require students to search through notes or other resources.

Students may see an inability to remember as an obstacle, but they should be encouraged to understand that this is an opportunity for learning to take place. By trying to recall information, students exercise or strengthen their memory and may also identify gaps in their learning. The more difficult the retrieval practice, the better it can be for long-term learning.

Interleaving

Interleaving involves interspersing the concepts, categories, skills or types of questions that students focus on in class or revision. This is in contrast to blocking, in which these elements are grouped together in a block of time. For example, for concepts A, B and C:

- Blocking A A A A A B B B B B C C C C C
- Interleaving A B C B C A B A C A C B C A B

Studies have found that interleaving in instruction or revision produces better long-term recall of subject matter. Interleaving also ensures that spacing occurs, as instances of practice are spread out over time.

Additionally, because exposure to one concept is interleaved with exposure to another, students have more opportunities to distinguish between related concepts. This highlighting of differences may explain why studies have found that interleaving enhances inductive learning, where participants use exemplars to develop an understanding of broader concepts or categories. Spacing without interleaving does not appear to benefit this type of learning.

Interleaving can seem counterintuitive — even in studies where interleaving enhanced learning, participants often felt that they had learnt more with blocked study. Despite this, their performance in testing indicated greater learning through the interleaving approach.

[1] Based on Agarwal, Roediger, McDaniel & McDermott (2020); Birnbaum, Kornell, Ligon Bjork & Bjork (2013); Carpenter & Agarwal (2020); Chen, Paas & Sweller (2021); Ebbinghaus (1885); Rohrer (2012); Taylor & Rohrer (2010).

Reporting

General information about determining and reporting results for senior syllabuses is provided in the 'Determining and reporting results' section of the *QCE and QCIA policy and procedures handbook*.

Reporting standards

Reporting standards are summary statements that describe typical performance at each of the five levels (A–E).

A
The student accurately describes a variety of concepts, theories, models and systems, and their limitations. They give clear and detailed accounts of a variety of concepts, theories, models and systems by making relationships, reasons or causes evident. The student communicates effectively by using scientific representations and language accurately and concisely within appropriate genres. They efficiently collect, collate and process relevant evidence. The student accurately applies their understanding of scientific concepts, theories, models and systems within their limitations to explain a variety of phenomena, and predict outcomes, behaviours and implications. They accurately use representations of scientific relationships and data to determine a variety of unknown scientific quantities and perceptively recognise the limitations of models and theories when discussing results. The student analyses systematically and effectively by identifying the essential elements, features or components of qualitative data. They use relevant mathematical processes to appropriately identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence insightfully by using their knowledge and understanding to draw justified conclusions based on their thorough analysis of evidence and established criteria. The student critically evaluates conclusions, claims and processes by insightfully scrutinising evidence, extrapolating credible findings, and discussing the reliability and validity of experiments. They investigate phenomena by carrying out effective experiments and research investigations.
B
The student accurately describes concepts, theories, models and systems, and their limitations. They give clear and detailed accounts of concepts, theories, models and systems by making relationships, reasons or causes evident. The student communicates accurately by using scientific representations and language within appropriate genres to present information. They collect, collate and process relevant evidence. The student accurately applies their understanding of scientific concepts, theories, models and systems within their limitations to explain phenomena and predict outcomes, behaviours and implications. They accurately use representations of scientific relationships and data to determine unknown scientific quantities, and accurately recognise the limitations of models and theories when discussing results. The student analyses effectively by identifying the essential elements, features or components of qualitative data. They use mathematical processes to appropriately identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence by using their knowledge and understanding to draw reasonable conclusions based on their accurate analysis of evidence and established criteria. The student evaluate processes, claims and conclusions by scrutinising evidence, applying relevant findings and discussing the reliability and validity of experiments. They investigate phenomena by carrying out effective experiments and research investigations.

C
The student describes concepts, theories, models and systems, and their limitations. They give detailed accounts of concepts, theories, models and systems by making relationships, reasons or causes evident. The student communicates using scientific representations and language within appropriate genres to present information. They collect, collate and process evidence. The student applies their understanding of scientific concepts, theories, models and systems within their limitations to explain phenomena and predict outcomes, behaviours and implications. They use representations of scientific relationships and data to determine unknown scientific quantities and recognise the limitations of models and theories when discussing results. The student analyses by identifying the essential elements, features or components of qualitative data. They use mathematical processes to identify trends, patterns, relationships, limitations and uncertainty in quantitative data. They interpret evidence by using their knowledge and understanding to draw conclusions based on their analysis of evidence and established criteria. The student evaluates processes, claims and conclusions by describing the quality of evidence, applying findings, and describing the reliability and validity of experiments. They investigate phenomena by carrying out experiments and research investigations.
D
The student describes and gives accounts of aspects of concepts, theories, models and systems. The student uses scientific representations or language to present information. They use rudimentary representations of scientific relationships or data to determine unknown scientific quantities or variables. The student analyses by identifying the elements, features or components of qualitative data. They use parts of mathematical processes to identify trends, patterns, relationships, limitations or uncertainty in quantitative data. They interpret evidence by drawing conclusions based on evidence or established criteria. The student considers the quality of evidence and conclusions and discusses processes, claims or conclusions. They carry out aspects of experiments and research investigations.
E
The student describes scenarios and communicates by referring to representations of information. They discuss physical phenomena and evidence. They follow established methodologies in research situations. They discuss evidence. The student carries out elements of experiments and research investigations.

Determining and reporting results

Unit 1 and Unit 2

Schools make judgments on individual assessment instruments using a method determined by the school. They may use the reporting standards or develop an instrument-specific marking guide (ISMG). Marks are not required for determining a unit result for reporting to the QCAA.

The unit assessment program comprises the assessment instrument/s designed by the school to allow the students to demonstrate the unit objectives. The unit judgment of A–E is made using reporting standards.

Schools report student results for Unit 1 and Unit 2 to the QCAA as satisfactory (S) or unsatisfactory (U). Where appropriate, schools may also report a not rated (NR).

Units 3 and 4

Schools mark each of the three internal assessment instruments implemented in Units 3 and 4 using ISMGs.

Schools report a provisional mark by criterion to the QCAA for each internal assessment.

Once confirmed by the QCAA, these results will be combined with the result of the external assessment developed and marked by the QCAA.

The QCAA uses these results to determine each student’s subject result as a mark out of 100 and as an A–E.

Units

Unit 1: Thermal, nuclear and electrical physics

In Unit 1, students explore the ways Physics is used to describe, explain and predict the energy transfers and transformations that are pivotal to modern industrial societies. An understanding of heating processes, nuclear reactions and electricity is essential to appreciate how global energy needs are met. Students investigate heating processes, apply the nuclear model of the atom to investigate radioactivity, and learn how nuclear reactions convert mass into energy. They examine the movement of electrical charge in circuits and use this to analyse and design electrical circuits.

Contexts that could be investigated in this unit include technologies related to nuclear and thermal energy, electrical energy production, radiopharmaceuticals and electricity in the home; and related areas of science such as nuclear fusion in stars. Through the investigation of these contexts, students may explore the challenge of meeting world energy needs and the ways in which science knowledge interacts with social, economic, cultural and ethical factors.

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills while gaining an enhanced appreciation of heating processes, ionising radiation, nuclear reactions and electric circuits. Collaborative experimental work also helps students to develop communication, interaction, character and management skills.

Throughout the unit, students develop skills in interpreting, constructing and using a range of algebraic, graphical and symbolic representations to describe, explain and predict energy transfers and transformations.

Unit objectives

1. Describe ideas and findings about heating processes, ionising radiation and nuclear reactions, and electrical circuits.
2. Apply understanding of heating processes, ionising radiation and nuclear reactions, and electrical circuits.
3. Analyse data about heating processes, ionising radiation and nuclear reactions, and electrical circuits.
4. Interpret evidence about heating processes, ionising radiation and nuclear reactions, and electrical circuits.
5. Evaluate processes, claims and conclusions about heating processes, ionising radiation and nuclear reactions, and electrical circuits.
6. Investigate phenomena associated with heating processes, ionising radiation and nuclear reactions, and electrical circuits.

Subject matter

Topic 1: Heating processes (15 hours)

Science understanding

Kinetic particle model and specific heat capacity

- Describe the kinetic particle model of matter.
- Describe the concepts of thermal energy, temperature, kinetic energy, heat and internal energy.
- Explain heat transfers in terms of conduction, convection and radiation.
- Use $T_K = T_C + 273$ to convert temperature measurements.
- Explain that a change in temperature is due to the addition or removal of energy from a system (without phase change).
- Describe the concept of specific heat capacity.
- Solve problems involving specific heat capacity using $Q = mc\Delta T$ (using but not limited to $c_i = 2.05 \times 10^3\ \mathrm{J\ kg^{-1}\ K^{-1}}$, $c_s = 2.00 \times 10^3\ \mathrm{J\ kg^{-1}\ K^{-1}}$ and $c_w = 4.18 \times 10^3\ \mathrm{J\ kg^{-1}\ K^{-1}}$.
- Interpret data from specific heat capacity experiments.

Phase changes and energy conservation

- Explain, in terms of the internal energy of a system and the kinetic particle model of matter, why the temperature of a system remains the same during the process of state change.
- Describe the concept of specific latent heat.
- Solve problems involving specific latent heat using $Q = mL$.
- Describe the concept of thermal equilibrium in terms of the temperature and average kinetic energy of the particles in each of the systems.
- Explain the process in which thermal energy is transferred between two systems until thermal equilibrium is achieved, and recognise the relevance of this to the laws of thermodynamics.
- Solve problems involving specific heat capacity, specific latent heat and thermal equilibrium.
- Explain how a system with thermal energy has the capacity to do mechanical work.
- Explain that the change in the internal energy of a system is equal to the energy added or removed by heating plus the work done on or by the system, and recognise this as the first law of thermodynamics and that this is a consequence of the law of conservation of energy.
- Explain how energy transfers and transformations in mechanical systems always result in some heat loss to the environment, so that the amount of useable energy is reduced.
- Describe the concept of efficiency.
- Solve problems involving the efficiency of heat transfers using $\Delta U = Q + W$ and $\eta = \frac{\text{energy output}}{\text{energy input}} \times \frac{100}{1}\%$.

Science as a human endeavour (SHE)

- Recognise that the science of heating processes is of key importance to the development of efficient and cost-effective technologies that use sustainable and renewable energy sources.
- Explore the development of new technologies and understandings of heating processes as a means to predicting global temperatures and the effects of human-induced climate change.
- Explore how the need for increases to the efficiency of early steam engines led to further technological advancements (e.g. the internal combustion engine) and scientific advancements (e.g. an understanding of, and mathematical articulation of, the relationship between heating processes and mechanical work).
- Appreciate that different temperature scales (e.g. Celsius, Fahrenheit, Kelvin) were developed at different times to serve different purposes.

Science inquiry

- Consider the significance of using common units of measurement internationally.
- Investigate the precision and accuracy of different temperature measuring devices, such as analogue and digital thermometers, by determining measurement uncertainty.
- Use digital and other measuring devices to collect data, ensuring measurements are recorded using the correct symbol, SI unit, number of significant figures and associated measurement uncertainty (absolute and percentage); all experimental measurements should be recorded in this way.
- Consider the energy contained within a cup of coffee versus a swimming pool.
- Explore the properties of water that makes it ideal for use as a coolant in car engines.
- Consider why you feel colder when you are wearing wet clothes.
- Investigate the proportional relationship between heat and temperature change.
- Investigate specific heat capacity of a substance.
- Explore why it is possible to boil water in a paper cup on a campfire.
- Explore the implications on availability of useable energy in the future if useable energy is reduced every time an energy transfer occurs.
- Investigate percentage error by comparing the theoretical and measured temperatures of a mixture of two liquids.

Topic 2: Ionising radiation and nuclear reactions (15 hours)

Science understanding

Nuclear model and stability

- Describe the nuclear model of the atom characterised by a small nucleus surrounded by electrons.
- Describe nuclides using $^{A}_{Z}X$ nomenclature.
- Explain why protons in the nucleus repel each other.
- Describe the concept of the strong nuclear force.
- Explain the stability of a nuclide in terms of the operation of the strong nuclear force over very short distances, electrostatic repulsion, and the relative number of protons and neutrons in the nucleus.

- Explain natural radioactive decay in terms of stability.
- Describe alpha, beta positive, beta negative and gamma radiation, including the properties of penetrating ability, charge, mass and ionisation ability.
- Explain how an excess of mass, protons, or neutrons in a nucleus can result in alpha, beta positive and beta negative decay.
- Solve problems involving balancing nuclear equations.
- Describe spontaneous alpha, beta positive and beta negative decay using decay equations.
- Explain how a radionuclide will, through a series of spontaneous decays, become a stable nuclide.
- Describe the concept of half-life.
- Solve radioactive decay problems using $N = N_o(\frac{1}{2})^n$ and other arithmetic or graphical methods.

Energy and mass defect

- Describe energy in terms of electron volts (eV) and joules (J).
- Describe the concept of artificial transmutation.
- Describe nuclear fission and nuclear fusion with the aid of nuclear equations.
- Distinguish between artificial transmutations and natural radioactive decay.
- Explain a neutron-induced nuclear fission reaction, including references to extra neutrons produced from many of these reactions.
- Explain a fission chain reaction.
- Describe the concepts of mass defect, binding energy and binding energy per nucleon.
- Describe the mass–energy equivalence relationship.
- Solve problems involving the mass–energy equivalence relationship using $\Delta E = \Delta mc^2$.
- Explain that more energy is released per nucleon in nuclear fusion than in nuclear fission because a greater percentage of the mass is transformed into energy.

Science as a human endeavour (SHE)

- Appreciate the significant contributions of scientists such as Marie Curie, Irene Joliot-Curie, Lise Meitner and Otto Hahn who furthered our understanding of radiation and nuclear stability.
- Appreciate that the development of models of the atom often required a wide range of evidence from multiple individuals and across disciplines.
- Explore advances in medical treatment and imaging that have come from a deepening understanding of the properties of nuclear radiation.
- Consider how scientific knowledge can be used to predict beneficial and/or harmful or unintended consequences, e.g. choosing appropriate radioisotopes for medical imaging, carefully storing nuclear waste.
- Consider how an understanding of radioactive decay can enable scientists to make reliable predictions in radiometric dating of materials.
- Consider the health and environmental risks associated with the use of nuclear fission along with the environmental and cost benefits of lowering fossil fuel consumption.
- Appreciate that energy production in stars was attributed to gravity until the knowledge of nuclear reactions led to the understanding that energy production in stars is due to nuclear fusion.

Science inquiry

- Consider whether nuclear fission-based power production could replace fossil fuel-based generation in Australia.
- Investigate nuclear safety, considering the suitability of using the sources of information in terms of their credibility.
- Examine exponential decay graphs and use these graphs to estimate half-lives.
- Investigate shielding effects and/or the relationship between intensity and distance from a radioactive source.

Topic 3: Electrical circuits (15 hours)

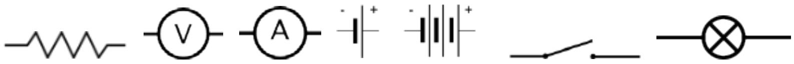
Science understanding

Current, potential difference and energy flow

- Describe electric charge as positive or negative.
- Describe electric current as carried by discrete electric charge carriers.
- Describe the law of conservation of electric charge.
- Explain that electric charge is conserved at all points in an electrical circuit.
- Describe the concepts of electrical potential difference and power within a circuit.
- Solve problems involving electric current, electric charge and time using $I = \frac{q}{t}$.
- Explain that the energy inputs in a circuit equal the sum of energy output from loads in the circuit.
- Explain that the energy available to electric charges moving in an electrical circuit is measured using electrical potential difference.
- Solve problems involving electrical potential difference using $V = \frac{W}{q}$.
- Explain in qualitative terms why electric charge separation produces an electrical potential difference.
- Solve problems involving power using $P = \frac{W}{t}$.
- Describe the concept of resistance.
- Solve problems using $V = IR$.
- Discuss the differences between ohmic and non-ohmic resistors.
- Interpret experimental data to determine the resistance across an ohmic resistor.

Circuit analysis and design

- Describe the concept of power dissipation over resistors in a circuit.
- Construct electrical circuit diagrams using the following symbols



- Solve problems involving electrical potential difference, electric current, resistance and power.
- Describe series and parallel connections of components in electrical circuits.
- Solve problems involving finding equivalent resistance, electrical potential difference and electric currents in series and parallel circuits using $P = VI$, $P = I^2R$, $V_t = V_1 + V_2 + \cdots V_n$, $R_t = R_1 + R_2 + \cdots R_n$, $I_t = I_1 + I_2 + \cdots I_n$, $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \frac{1}{R_n}$.
- Describe simple series, parallel and series/parallel circuits.

Science as a human endeavour (SHE)

- Appreciate the significant contributions of scientists such as Gustav Kirchhoff, Georg Ohm, Hertha Ayrton and Florence Violet McKenzie who furthered our understanding of electrical currents.
- Appreciate how international conventions enable clear communication of ideas and findings across the globe, e.g. conventional current.
- Explore the impacts of increased use of household electrical devices during extreme weather, e.g. heat in Australian summers or cold in European winters.
- Appreciate how developing new household electrical devices to improve the efficiency of existing devices and ensure consistency of electrical standards requires international cooperation between scientists, engineers and manufacturers.
- Consider the impacts of computers, smartphones and the internet on society and their reliance on a stable supply of electricity.
- Explore the concerns about sustainable energy usage and global warming that have led to international research and development to improve the energy efficiency of electric lighting.

Science inquiry

- Compare characteristics of ohmic and non-ohmic resistors experimentally.
- Interpret graphical representations of electrical potential difference versus electric current data to find resistance using the gradient and its uncertainty.
- Investigate series and parallel circuits.
- Investigate simple circuits for specific ‘real-life’ purposes.

Unit 2: Linear motion and waves

In Unit 2, students develop an appreciation of how an understanding of motion and waves can be used to describe, explain and predict a wide range of phenomena. Students describe linear motion in terms of displacement, velocity, acceleration and time data, and examine the relationships between force, momentum and energy for interactions in one dimension. Students also investigate common wave phenomena, using waves on springs, sound waves and consideration of seismic waves. They compare the behaviour of these waves with the behaviour of light, leading to an explanation of light phenomena, including constructive and destructive interference, and diffraction, in terms of a wave model.

Contexts that could be investigated in this unit include technologies (such as accelerometers, motion detectors, photo radar, energy conversion buoys, music, hearing aids, echo locators, fibre optics, DVDs and lasers) and related areas of science and engineering (such as sports science, car and road safety, acoustic design, noise pollution, seismology, bridge and building design).

Participation in a range of experiments and investigations will allow students to progressively develop their suite of science inquiry skills, while gaining an enhanced appreciation of the range of technologies that have contributed to the development of physics understanding. Collaborative experimental work also helps students to develop communication, interaction, character and management skills.

Throughout the unit, students also develop their understanding of motion and wave phenomena through laboratory investigations. They develop skills in relating graphical representations of data to quantitative relationships between variables, and continue to develop skills in planning and conducting investigations and interpreting the results.

Unit objectives

1. Describe ideas and findings about linear motion and force, and waves.
2. Apply understanding of linear motion and force, and waves.
3. Analyse data about linear motion and force, and waves.
4. Interpret evidence about linear motion and force, and waves.
5. Evaluate processes, claims and conclusions about linear motion and force, and waves.
6. Investigate phenomena associated with linear motion and force, and waves.

Subject matter

Topic 1: Linear motion and force (25 hours)

Science understanding

Linear motion

- Contrast vectors and scalars, and use these terms to categorise physical quantities, e.g. velocity and speed.
- Symbolise vectors graphically and algebraically, e.g. F, $\tilde{\mathrm{F}}$ and $\vec{\mathrm{F}}$.
- Calculate resultant vectors through the addition and subtraction of two vectors in one dimension.
- Describe the concepts of displacement, velocity and acceleration.
- Compare instantaneous and average velocity.
- Interpret linear motion graphs to describe the motion of an object, referring to the
  - intercepts, gradients and uncertainties (using minimum and maximum lines of best fit) of displacement–time and velocity–time graphs
  - areas under velocity–time and acceleration–time graphs using simple geometry.
- Solve problems relating to uniformly accelerated motion in one dimension using $v = u + at$, $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$.
- Interpret experimental data to determine the value of acceleration due to gravity on the Earth's surface.

Classical mechanics

- Describe the three laws of motion of classical mechanics and give examples of each.
- Identify forces acting on an object.
- Construct free-body diagrams representing forces such as the force due to gravity (weight), the normal force, tension, friction, drag and applied forces acting on an object.
- Determine the resultant force acting on an object in one dimension.
- Solve problems using the laws of classical mechanics and $a = \frac{F_{net}}{m}$.
- Describe the concepts of momentum and impulse.
- Describe the principle of conservation of momentum.
- Solve problems involving momentum, impulse, the conservation of momentum and collisions in one dimension using $p = mv$ and $\sum mv_{before} = \sum mv_{after}$.
- Analyse the area under a force–time graph using geometric methods.

Energy

- Describe the concepts of mechanical work, kinetic energy and gravitational potential energy.
- Solve problems involving work done by a force using $W = \Delta E$ and $W = Fs$.
- Solve problems involving kinetic energy and gravitational potential energy using $E_k = \frac{1}{2}mv^2$ and $\Delta E_p = mg\Delta h$.
- Analyse the area under a force–displacement graph using geometric methods.
- Interpret energy–time graphs.
- Discuss the differences between elastic and inelastic collisions.
- Solve problems involving elastic collisions and inelastic collisions (including explosions) using $\sum\frac{1}{2}mv_{before}^2 = \sum\frac{1}{2}mv_{after}^2$.

Science as a human endeavour (SHE)

- Appreciate the significant contributions of scientists such as Isaac Newton and Émilie du Châtelet.
- Explore historical models and theories used to describe motion and force, and how evidence was used to build upon and improve on earlier understandings.
- Consider how knowledge of forces and motion has led to improvements in car safety through the development of technologies such as seatbelts, crumple zones and airbags.
- Understand the study of biomechanics applies the laws of forces and motion, and through direct measurement, computer simulation and mathematical modelling lead to a better understanding of human movement and improved athletic performance.
- Appreciate that the laws of motion proposed by Isaac Newton provided an explanation for a range of previously unexplained physical phenomena, which were confirmed by multiple experiments performed by a multitude of scientists.

Science inquiry

- Explore the variations in final position of a person who walks 100 m.
- Consider the fable of the tortoise and the hare, and how the slow-moving tortoise was able to beat the faster hare.
- Explore the role physics plays in improving the performance of elite athletes.
- Investigate situations that involve displacement–time and velocity–time graphs.
- Use vertical error bars when plotting data to determine the uncertainty of the gradient and intercepts using minimum and maximum lines of best fit.
- Investigate a linear elastic collision between two objects.
- Linearise a dataset that suggests a non-linear relationship (e.g. t^2 versus s) and calculate the equation of the linear trend line.

Topic 2: Waves (20 hours)

Science understanding

Wave properties

- Describe the transfer of energy through waves.
- Describe the concept of mechanical waves.
- Compare transverse waves and longitudinal waves.
- Describe examples of transverse and longitudinal waves, such as sound, seismic waves and vibrations of stringed instruments.
- Describe the concepts of compression, rarefaction, crest, trough, displacement, amplitude, period, frequency, wavelength and velocity and identify them on graphical and visual representations of a wave.
- Analyse the amplitude, period, frequency and wavelength from graphs of transverse and longitudinal waves.
- Solve problems involving the period, frequency, wavelength, and velocity of a wave using $v = f\lambda$ and $f = \frac{1}{T}$ and using but not limited to $v_s = 346 \text{ m s}^{-1}$.
- Describe the concepts of reflection, refraction, diffraction and superposition.
- Explain phenomena related to reflection and refraction using the wave model of light.
- Describe the reflection and refraction of a wave at a boundary between two media.
- Explain constructive interference and destructive interference of two simple waves.
- Determine the resultant amplitude of two simple waves interacting using the principle of superposition.
- Explain the formation of standing waves in terms of superposition with reference to constructive and destructive interference, and nodes and antinodes.

Sound

- Describe the concepts of fundamental (or first) harmonic and natural frequency.
- Solve problems involving standing wave formation in pipes open at both ends, closed at one end, and on stretched strings using $L = n\frac{\lambda}{2}$ and $L = (2n-1)\frac{\lambda}{4}$.
- Describe the concept of resonance in a mechanical system.
- Identify that energy is transferred efficiently in resonating systems.

Light

- Compare light to a mechanical wave.
- Explain the concepts of reflection, refraction, total internal reflection, dispersion, diffraction and interference in relation to the wave model of light.
- Describe polarisation using a transverse wave model.
- Construct ray diagrams to demonstrate the reflection and refraction of light.
- Solve problems involving the reflection of light on single plane mirrors and refraction of light through a single convex or concave lens using ray diagrams to identify the location, orientation and size of an image.
- Describe the concept of Snell's Law.
- Solve problems involving the refraction of light at the boundary between two mediums using $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$.
- Contrast the speed of light and the speed of mechanical waves.
- Describe the concept of intensity and its proportionality to the square of the amplitude.
- Solve problems involving the proportional relationship between intensity of light and the inverse-square of the distance from the source using $I \propto \frac{1}{r^2}$.
- Determine the refractive index of a transparent substance from experimental data.

Science as a human endeavour (SHE)

- Appreciate the significant contributions of scientists such as Laura Bassi, Willebrord Snellius, Albert A Michelson and Edward W Morley.
- Appreciate the role of experiments in furthering our understanding of light and its wave-like behaviour.
- Consider the importance of wave properties in experiments such as those performed by Michelson and Morley to demonstrate light waves travel through a vacuum and not the luminiferous aether as was believed at the time.
- Appreciate that knowledge of different types of waves, and their motion through the ocean and the continents, allows prediction of the possible extent of damage or the timing of a tsunami.
- Consider how acoustical engineering can reduce noise pollution by planning structures that absorb sound waves or that do not reflect and amplify sound in an unwanted way.

Science inquiry

- Consider the apparent position of objects under water in relation to observations made through different media.
- Investigate the behaviour of both longitudinal waves and transverse waves on springs in relation to reflection from fixed and free ends and transmission/reflection at a medium boundary.
- Investigate fundamental and harmonic wavelengths in pipes.
- Investigate the speed of sound in air at a specific temperature.
- Investigate the law of reflection.
- Investigate the refractive properties of different substances.

Unit 3: Gravity and electromagnetism

In Unit 3, students develop a deeper understanding of motion and its causes by using Newton's laws of motion and the gravitational field model to analyse motion on inclined planes, and the motion of projectiles and satellites. Field theories have enabled physicists to explain a vast array of natural phenomena and have contributed to the development of technologies that have changed the world, including electrical power generation and distribution systems, artificial satellites and modern communication systems. Students develop their understanding of field theories of gravity and electromagnetism through investigations of motion and electromagnetic phenomena. Finally, they will investigate the production of electromagnetic waves.

Contexts that could be investigated in this unit include technologies such as artificial satellites, navigation devices, large-scale electrical power generation and distribution, motors and generators, electric cars, synchrotron science, medical imaging and astronomical telescopes such as the Square Kilometre Array, and related areas of science and engineering such as sports science, amusement parks, ballistics, forensics, black holes and dark matter.

Participation in a range of experiments and investigations will allow students to develop skills in relating graphical representations of data to quantitative relationships between variables, using lines of force to represent vector fields, and interpreting interactions in two and three dimensions.

Throughout the unit, students develop skills in planning and conducting investigations, interpreting results and evaluating the validity of primary and secondary data, as well as the communication of these evaluations to others in a range of formats.

Unit objectives

1. Describe ideas and findings about gravity and motion, and electromagnetism.
2. Apply understanding of gravity and motion, and electromagnetism.
3. Analyse data about gravity and motion, and electromagnetism.
4. Interpret evidence about gravity and motion, and electromagnetism.
5. Evaluate processes, claims and conclusions about gravity and motion, and electromagnetism.
6. Investigate phenomena associated with gravity and motion, and electromagnetism.

Subject matter

Topic 1: Gravity and motion (22 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

Projectile motion

- Apply vector analysis to resolve a vector into two perpendicular components.
- Solve vector problems by resolving vectors into components, adding or subtracting the components and recombining them to determine the resultant vector.
- Describe how horizontal and vertical components of a velocity vector are independent of each other.
- Solve problems involving projectile motion in the absence of drag effects using $v_y = u_y + gt$, $s_y = u_y t + \frac{1}{2}gt^2$, $v_y^2 = u_y^2 + 2gs_y$, $v_x = u_x$ and $s_x = u_x t$.
- Interpret data relating to the horizontal distance travelled by an object projected at various angles from the horizontal.

Inclined planes and circular motion

- Solve problems involving force due to gravity (weight) and mass using $F_g = mg$.
- Describe the concept of normal force.
- Describe the forces acting on an object on an inclined plane (e.g. force due to gravity, normal force, tension, frictional force and applied force) through the use of free-body diagrams.
- Determine the net force acting on an object on an inclined plane using vector analysis.
- Describe the concept of uniform circular motion.
- Describe the concepts of average speed and period.
- Solve problems involving objects undergoing uniform circular motion at a constant speed using $v = \frac{2\pi r}{T}$ and $a_c = \frac{v^2}{r}$.
- Describe the concepts of centripetal acceleration and centripetal force.
- Solve problems involving forces acting on objects in uniform circular motion using $F_c = F_{net} = \frac{mv^2}{r}$.

Orbital mechanics

- Describe the Law of Universal Gravitation.
- Solve problems involving the magnitude of the gravitational force between two masses using $F = \frac{GMm}{r^2}$.
- Describe the concept of gravitational fields.
- Solve problems involving the gravitational field strength at a distance from an object using $g = \frac{F}{m} = \frac{GM}{r^2}$.
- State the three laws of planetary motion.
- Describe the relationship between the Law of Universal Gravitation and uniform circular motion and recognise this as the third law of planetary motion.
- Solve problems involving the third law of planetary motion using $\frac{{T_a}^2}{{r_a}^3} = \frac{{T_b}^2}{{r_b}^3} = \frac{4\pi^2}{GM}$.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Appreciate the significant contributions of scientists such as Isaac Newton, Johannes Kepler, Émilie du Châtelet and Katherine Johnson who furthered our understanding of gravity and motion.
- Explore the role of forensic evidence used in court and the challenges associated with providing conclusive evidence that may lead to convictions.
- Appreciate how the accepted model of the solar system slowly shifted under the influence of carefully collected and analysed data.
- Explore the difficulties experienced by scientists who supported a heliocentric model of the solar system and the hindrances to the acceptance of their discoveries by society.
- Consider the international collaboration required to monitor the orbits of satellites, and the management of space debris.
- Consider the factors that contribute to positioning of satellites used for observation of weather, natural phenomena, traffic and military movements.
- Explore the international collaboration required in the discovery of gravity waves and associated technologies, e.g. Laser Interferometer Gravitational Wave Observatory (LIGO).

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Consider how an object can travel at a constant speed yet be accelerating.
- Investigate the horizontal distance travelled by an object projected at various angles from the horizontal.
- Investigate the parallel component of the weight of an object down an inclined plane at various angles.
- Investigate the net forces acting on an object undergoing horizontal circular motion on a string.
- Consider the difference between the heliocentric and geocentric models of the solar system.
- Investigate the relationship between orbital radius and mass for orbiting objects using a simulation.

Topic 2: Electromagnetism (23 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

Electrostatics

- Describe Coulomb's Law.
- Solve problems using $F = \frac{1}{4\pi\varepsilon_o}\frac{Qq}{r^2} = \frac{kQq}{r^2}$.
- Describe the concepts of electric fields, electric field strength and electrical potential energy.
- Solve problems involving electric field strength using $E = \frac{F}{Q} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2} = \frac{kq}{r^2}$.
- Solve problems involving the work done when an electric charge is moved in an electric field using $V = \frac{\Delta U}{q}$.

Magnetic fields

- Describe the concept of a magnetic field.
- Sketch magnetic field lines due to a moving electric charge, electric currents and magnets.
- Describe the generation of a magnetic field from a moving electric charge.
- Solve problems involving the magnitude and direction of magnetic fields around a straight electric current-carrying wire and inside a solenoid using $B = \frac{\mu_o I}{2\pi r}$ and $B = \mu_o nI$.
- Describe the force experienced by electric current-carrying conductors and moving electric charges when placed in a magnetic field.
- Solve problems involving the magnetic force on an electric current-carrying wire and moving charge in a magnetic field using $F = BILsin\theta$ and $F = qvBsin\theta$.
- Interpret data relating to the force acting on a conductor in a magnetic field.
- Interpret data relating to the strength of a magnet at various distances.

Electromagnetic induction

- Describe the concepts of magnetic flux, magnetic flux density, electromagnetic induction, electromotive force (EMF), Faraday's Law and Lenz's Law.
- Solve problems involving the magnetic flux in an electric current-carrying loop using $\emptyset = BAcos\theta$.
- Describe the process of inducing an EMF across a moving conductor in a magnetic field.
- Explain how Lenz's Law is consistent with the principle of conservation of energy.
- Explain how transformers work in terms of Faraday's Law and electromagnetic induction.
- Solve problems involving electromagnetic induction using $emf = -\frac{N\Delta(BA_\perp)}{\Delta t}$, $emf = -N\frac{\Delta\phi}{\Delta t}$, $I_pV_p = I_sV_s$ and $\frac{V_p}{V_s} = \frac{N_p}{N_s}$.
- Describe the concept of an electromagnetic wave.
- Explain the relationship between oscillating electric charges and electromagnetic waves.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Appreciate the significant contributions of scientists such as Charles-Augustin de Coulomb, Michael Faraday, Emil Lenz, Mary Somerville and James Clerk Maxwell who furthered our understanding of electromagnetism.
- Explore how scientific knowledge has allowed the development of new methods for renewable energy production.
- Consider the scientific evidence concerning the risks of electromagnetic phenomena and associated technologies (e.g. wi-fi and mobile phones) as reported in the media.
- Explore the international collaboration involved in the development of the Square Kilometre Array (SKA) and the associated technologies to gather information that advances our knowledge of dark matter, dark energy, cosmic magnetism and general relativity.
- Consider the safety procedures developed for instruments that rely on strong magnetic fields (e.g. MRI and NMR machines).
- Explore the discoveries and theories that led to our current understanding of superconductivity.

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Investigate the force acting on a conductor in a magnetic field.
- Investigate the strength of a magnet at various distances.
- Investigate the effects of electrostatic charge on various materials, e.g. on trickling water.
- Consider how electricity is made.
- Investigate the induction of an electric current using a magnet and coil.
- Investigate the induced EMF from an AC generator.

Unit 4: Revolutions in modern physics

In Unit 4, students examine observations of relative motion, light and matter that could not be explained by classical physics theories, and investigate how the shortcomings of existing theories led to the development of the special theory of relativity and the quantum theory of light and matter. The development of quantum theory and the theory of relativity fundamentally changed our understanding of how nature operates and led to the development of a wide range of new technologies, including those that revolutionised the storage, processing and communication of information. Students evaluate the contribution of the quantum theory of light to the development of the quantum theory of the atom, and examine the Standard Model of particle physics and how it relates to the Big Bang theory.

Contexts that could be investigated in this unit include technologies such as GPS navigation, lasers, modern electric lighting, medical imaging, quantum computers and particle accelerators, and related areas of science such as space travel, the digital revolution and the greenhouse effect.

Participation in a range of experiments and investigations will allow students to apply their understanding of relativity, black-body radiation, wave–particle duality and the quantum theory of the atom to make and/or explain observations of a range of phenomena such as atomic emission and absorption spectra, the photoelectric effect, lasers and Earth's energy balance.

Throughout the unit, students develop skills in planning and conducting investigations, interpreting results, synthesising evidence to support conclusions, recognising and defining the realm of validity of physical theories and models, and communicating these conclusions to others in a range of formats.

Unit objectives

1. Describe ideas and findings about special relativity, quantum theory and the Standard Model.
2. Apply understanding of special relativity, quantum theory and the Standard Model.
3. Analyse data about special relativity, quantum theory and the Standard Model.
4. Interpret evidence about special relativity, quantum theory and the Standard Model.
5. Evaluate processes, claims and conclusions about special relativity, quantum theory and the Standard Model.
6. Investigate phenomena associated with special relativity, quantum theory and the Standard Model.

Subject matter

Topic 1: Special relativity (16 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

Special relativity

- Describe observations of natural phenomena that cannot be explained by classical physics, e.g. the presence of muons in the atmosphere and the momentum of high speed particles in particle accelerators.
- Describe the concepts of frame of reference and inertial frame of reference.
- State the two postulates of special relativity.
- Explain how motion can only be measured relative to an observer.
- Explain the concept of simultaneity.
- Describe the consequences of the constant speed of light in a vacuum, e.g. time dilation and length contraction.
- Describe the concepts of time dilation, proper time interval, relativistic time interval, length contraction, proper length, relativistic length, rest mass and relativistic momentum.
- Describe the phenomena of time dilation and length contraction, including examples of experimental evidence of the phenomena.
- State the mass–energy equivalence relationship.
- Solve problems involving time dilations, length contraction and relativistic momentum using $t = \frac{t_o}{\sqrt{(1-\frac{v^2}{c^2})}}$, $L = L_o\sqrt{(1-\frac{v^2}{c^2})}$, $p_v = \frac{m_o v}{\sqrt{(1-\frac{v^2}{c^2})}}$ and $\Delta E = \Delta mc^2$.
- Explain the implications of relativistic momentum of objects increasing as they approach the speed of light.
- Explain paradoxical scenarios that may arise as a result of special relativity including the twins' paradox, flashlights on a train, and the ladder in the barn paradox.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Appreciate the significant contributions of scientists such as Albert Einstein and Amalie 'Emmy' Noether who furthered our understanding of relativity.
- Explore how special relativity built upon the work of previous scientists and led to the development of relativistic theories of gravitation, mass–energy equivalence and quantum field theory.
- Explore how technologies such as satellites have dramatically increased the size, accuracy, and geographic and temporal scope of datasets with which scientists work.
- Explore how technologies such as GPS and Ring laser gyroscopes (RLG) assist with accurate navigation and consider the ethics surrounding their use.
- Explore how special relativity leads to the idea of mass–energy equivalence, which has subsequently been applied in nuclear fission reactors.

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Consider whether information could be transmitted at speeds faster than the speed of light.
- Consider the experimental evidence that supports the phenomena of time dilation and its real-world applications.
- Explore why the speed of light is the maximum possible speed in our universe.

Topic 2: Quantum theory (16 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

Quantum theory

- Explain how the double slit experiment provides evidence for the wave model of light.
- Describe light as an electromagnetic wave.
- Explain the concept of black-body radiation and the significance of the evidence it provides.
- Describe the photoelectric effect in terms of the photon.
- Describe the concepts of threshold frequency and work function.
- Solve problems involving blackbody radiation and the photoelectric effect using $\lambda_{max} = \frac{b}{T}$, $E = hf = \frac{hc}{\lambda}$, $E_k = hf - W$, $W = hf_0$.
- Compare the different models of the atom proposed by Rutherford and Bohr.
- Explain how Bohr's model of the hydrogen atom integrates light quanta and atomic energy states to explain the specific wavelengths in the hydrogen line spectrum.
- Solve problems involving the line spectra of simple atoms using atomic energy states or atomic energy level diagrams using $n\lambda = 2\pi r$, $mvr = \frac{nh}{2\pi}$, $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ and $\lambda = \frac{h}{p}$.
- Describe wave–particle duality of light by identifying evidence that supports the wave characteristics of light and evidence that supports the particle characteristics of light.
- Interpret data related to the photoelectric effect.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Appreciate the significant contributions of scientists such as Wilhelm Wien, Max Planck, Ernest Rutherford, Niels Bohr, Maria Goeppert-Mayer and Johannes Rydberg who furthered our understanding of quantum theory.
- Explore the historical development of the model of the atom in terms of traditional models.
- Consider how theories are contested, refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power.
- Explore how the approximation of Earth as a black body can be used to predict climate patterns.

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Investigate variables related to the photoelectric effect such as
  - photoelectron energy or velocity
  - electrical potential difference across the anode and cathode
  - wavelength or frequency of incident light
  - work functions of surfaces.

Topic 3: The Standard Model (13 hours)

Science understanding

The following subject matter can be assessed in the external assessment.

The Standard Model

- Describe the concepts of elementary particles and antiparticles.
- Identify the six types of quarks.
- Describe baryons and mesons.
- Identify the six types of leptons.
- Identify the four gauge bosons.
- Compare the strong nuclear, weak nuclear and electromagnetic forces in terms of the gauge bosons.
- Contrast the fundamental forces experienced by quarks and leptons.

Particle interactions

- Describe the concepts of lepton number and baryon number.
- Solve problems relating to the conservation of lepton number and baryon number in particle interactions using $B = n_b - n_{\bar{b}}$, $B = \frac{1}{3}(n_q - n_{\bar{q}})$ and $L = n_l - n_{\bar{l}}$.
- Describe electron/electron, electron/positron and neutron decay interactions using particle interaction diagrams.
- Describe how symmetry in particle interactions occurs to maintain the principles of conservation.

Science as a human endeavour (SHE)

The following subject matter may be assessed in the internal assessments.

- Appreciate the significant contributions of scientists such as Chien-Shiung Wu, Richard Feynman and Peter Higgs who furthered our understanding of particle physics and The Standard Model.
- Explore the history of particle physics models and theories through the development of particle accelerators and contributions from notable physicists.
- Appreciate that particle accelerators like the Australian Synchrotron and Large Hadron Collider are developed through multinational collaborations between science organisations and governments.
- Appreciate the contribution of Australian scientists to the discovery of the Higgs boson.
- Explore the evidence relating to the Standard Model that supports the Big Bang theory.

Science inquiry

The following subject matter may be assessed in the internal assessments.

- Examine evidence supporting theories related to particle physics.

Assessment

Internal assessment 1: Data test (10%)

Students respond to items using qualitative data and/or quantitative data derived from practicals, activities or case studies relevant to Unit 3 subject matter.

Assessment objectives

2. Apply understanding of gravity and motion, or electromagnetism to given algebraic, visual or graphical representations of scientific relationships and data to determine unknown scientific quantities or features.
3. Analyse data about gravity and motion, or electromagnetism to identify trends, patterns, relationships, limitations or uncertainty in datasets.
4. Interpret evidence about gravity and motion, or electromagnetism to draw conclusions based on analysis of datasets.

Specifications

The teacher provides an examination that may ask students to respond using:

- single words
- sentences (up to 150 words per question)
- calculations.

Question specifications

The examination must be aligned to the specifications provided in the table below.

Focus of question	Mark allocation (± 2%)	Objective	In these questions, students:
Unknown scientific quantities or features of datasets	~ 30%	2	calculate using algorithms, determine, identify, use
Trends, patterns, relationships, limitations or uncertainty in datasets	~ 30%	3	categorise, classify, compare, contrast, identify, organise, sequence
Conclusions based on analysis of datasets	~ 40%	4	deduce, determine, draw (a conclusion), extrapolate, infer, interpolate, justify, predict

Stimulus specifications

The teacher provides unseen stimulus that:

- uses qualitative data and/or quantitative data from the listed practicals, activities or case studies from Unit 3
- contains between two and four datasets.

Conditions

- Time allowed
  - Perusal time: 5 minutes
  - Working time: 60 minutes
- This is an individual supervised task.
- Students are permitted
  - a QCAA-approved graphics or scientific calculator
  - the QCAA Physics formula and data book.

Mark allocation

Criterion	Assessment objectives	Marks
Data test	2, 3, 4	10
	Total marks:	10

Instrument-specific marking guide (IA1)

Data test	Cut-off	Marks
The student response has the following characteristics:		
• consistent demonstration, across a range of scenarios, of - selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications - correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data - correct and appropriate use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty - correct interpretation of evidence to draw valid conclusions	> 90%	10
	> 80%	9
• consistent demonstration of - selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications - correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data - correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty - correct interpretation of evidence to draw valid conclusions	> 70%	8
	> 60%	7
• adequate demonstration of - selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications - correct calculation of quantities through the use of algebraic, visual and graphical representations of scientific relationships and data - correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations and uncertainty - correct interpretation of evidence to draw valid conclusions	> 50%	6
	> 40%	5
• demonstration of elements of - selection and correct application of scientific concepts, theories, models and systems to predict outcomes, behaviours and implications - correct calculation of quantities through the use of algebraic, visual or graphical representations of scientific relationships or data - correct use of analytical techniques to correctly identify trends, patterns, relationships, limitations or uncertainty - correct interpretation of evidence to draw valid conclusions	> 30%	4
	> 20%	3
• demonstration of elements of - application of scientific concepts, theories, models or systems to predict outcomes, behaviours or implications - calculation of quantities through the use of algebraic or graphical representations of scientific relationships and data - use of analytical techniques to identify trends, patterns, relationships, limitations or uncertainty - interpretation of evidence to draw conclusions.	> 10%	2
	> 1%	1
The student response does not match any of the descriptors above.	≤ 1%	0

Internal assessment 2: Student experiment (20%)

Students modify (i.e. refine, extend or redirect) an experiment relevant to Unit 3 subject matter to address their own related hypothesis or question. This assessment provides opportunities to assess science inquiry skills.

Assessment objectives

1. Describe ideas and experimental findings about gravity and motion, or electromagnetism.
2. Apply understanding of gravity and motion, or electromagnetism to modify experimental methodologies and process data.
3. Analyse experimental data about gravity and motion, or electromagnetism.
4. Interpret experimental evidence about gravity and motion, or electromagnetism.
5. Evaluate experimental processes and conclusions about gravity and motion, or electromagnetism.
6. Investigate phenomena associated with gravity and motion, or electromagnetism through an experiment.

Specifications

This task requires students to:

- identify an experiment to modify
- develop a research question to be investigated
- research relevant background scientific information to inform the modification of the research question and methodology
- conduct a risk assessment and account for risks in the methodology
- conduct the experiment
- collect relevant qualitative data and/or quantitative data to address the research question
- process and present the data appropriately
- analyse the evidence to identify trends, patterns or relationships
- analyse the evidence to identify uncertainty and limitations
- interpret the evidence to draw conclusion/s to the research question
- evaluate the reliability and validity of the experimental process
- suggest possible improvements and/or extensions to the experiment
- communicate findings in an appropriate scientific genre, e.g. report, poster presentation, journal article, conference presentation.

Scientific inquiry is a non-linear, iterative process. Students will not necessarily complete these steps in the stated order; some steps may be repeated or revisited.

It is recommended that this task is designed so that students can develop a response in approximately 10 hours of class time.

Conditions

- Students can develop their responses in class time and their own time.
- This is an individual task.
- The following aspects of the task may be completed as a group
  - identifying an experiment
  - developing a research question
  - conducting a risk assessment
  - conducting the experiment
  - collecting data.
- Students use a practical or simulation performed in class as the basis for their methodology and research question.

Response requirements

One of the following:

- Multimodal (at least two modes delivered at the same time): up to 11 minutes
- Written: up to 2000 words

Mark allocation

Criterion	Assessment objectives	Marks
Forming	1, 2, 6	5
Finding	1, 6	5
Analysing	2, 3	5
Interpreting and Evaluating	4, 5	5
	Total marks:	20

Instrument-specific marking guide (IA2)

Forming	Marks
The student response has the following characteristics:	
• a considered rationale for the experiment • justified modifications to the methodology • a specific and relevant research question • a methodology that enables the collection of sufficient and relevant data • appropriate use of genre and referencing conventions	4–5
• a reasonable rationale for the experiment • feasible modifications to the methodology • a relevant research question • a methodology that enables the collection of relevant data • use of basic genre and referencing conventions	2–3
• a vague or irrelevant rationale for the experiment • inappropriate modifications to the methodology • an inappropriate research question • a methodology that causes the collection of insufficient and irrelevant data • inadequate use of genre and referencing conventions.	1
The student response does not match any of the descriptors above.	0

Finding	Marks
The student response has the following characteristics:	
• considered management of risks/ethical issues/environmental issues • collection of sufficient and relevant raw data • fluent and concise use of scientific language and representations	4–5
• management of risks/ethical issues/environmental issues • collection of relevant raw data • competent use of scientific language and representations	2–3
• inadequate management of risks/ethical issues/environmental issues • collection of insufficient and irrelevant raw data • simplistic use of language and representations.	1
The student response does not match any of the descriptors above.	0

Analysing	Marks
The student response has the following characteristics:	
• correct and relevant processing of data • thorough identification of relevant trends/patterns/relationships • thorough and appropriate identification of the uncertainty and limitations of evidence	4–5
• basic processing of data • identification of obvious trends/patterns/relationships • basic identification of uncertainty and/or limitations of evidence	2–3
• incorrect or irrelevant processing of data • identification of incorrect or irrelevant trends/patterns/relationships • incorrect or insufficient identification of uncertainty and limitations of evidence.	1
The student response does not match any of the descriptors above.	0

Interpreting and Evaluating	Marks
The student response has the following characteristics:	
• justified conclusion/s linked to the research question • justified discussion of the reliability and validity of the experimental process • suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence	4–5
• reasonable conclusion/s relevant to the research question • reasonable description of the reliability and/or validity of the experimental process • suggested improvements and/or extensions to the experiment that are related to the analysis of evidence	2–3
• inappropriate or irrelevant conclusion/s • cursory or simplistic statements about the reliability and validity of the experimental process • ineffective or irrelevant suggestions.	1
The student response does not match any of the descriptors above.	0

Internal assessment 3: Research investigation (20%)

Students gather evidence related to a research question to evaluate a claim relevant to Unit 4 subject matter. This assessment provides opportunities to assess science inquiry skills and science as a human endeavour (SHE) subject matter.

Assessment objectives

1. Describe ideas and findings about special relativity, quantum theory or the Standard Model.
2. Apply understanding of special relativity, quantum theory or the Standard Model to develop research questions.
3. Analyse research data about special relativity, quantum theory or the Standard Model.
4. Interpret research evidence about special relativity, quantum theory or the Standard Model.
5. Evaluate research processes, claims and conclusions about special relativity, quantum theory or the Standard Model.
6. Investigate phenomena associated with special relativity, quantum theory or the Standard Model through research.

Specifications

This task requires students to:

- select a claim to be evaluated, from a list provided by the teacher
- identify the relevant scientific concepts associated with the claim
- conduct research to gather evidence from scientifically credible sources to evaluate the claim
- pose a research question that addresses an aspect of the claim
- identify relevant evidence to answer the research question
- identify the trends, patterns or relationships in the evidence
- analyse the evidence to identify limitations
- interpret the evidence to construct scientific arguments
- interpret the evidence to form a conclusion to the research question
- discuss the quality of the evidence
- evaluate the claim by applying the findings of the research to the claim
- suggest improvements and/or extensions to the investigation
- communicate findings in an appropriate scientific genre, e.g. report, journal article, essay, conference presentation.

Scientific inquiry is a non-linear, iterative process. Students will not necessarily complete these steps in the stated order; some steps may be repeated or revisited.

Evidence must be obtained by researching scientifically credible sources, such as:

- books and podcasts by well-credentialed scientists
- ‘popular’ science websites or magazines
- websites of governments, universities, independent research bodies or science and technology manufacturers
- scientific journals.

It is recommended that this task is designed so that students can develop a response in approximately 10 hours of class time.

Conditions

- Students can develop their responses in class time and their own time.
- This is an individual task.
- The following aspects of the task may be completed as a group
  - selecting a claim
  - identifying the relevant scientific concepts associated with the claim
  - conducting research.

Response requirements

One of the following:

- Multimodal (at least two modes delivered at the same time): up to 11 minutes
- Written: up to 2000 words

Mark allocation

Criterion	Assessment objectives	Marks
Forming and Finding	1, 2, 6	5
Analysing	3	5
Interpreting	1, 4	5
Evaluating	5	5
	Total marks:	20

Instrument-specific marking guide (IA3)

Forming and Finding	Marks
The student response has the following characteristics:	
• a considered rationale identifying clear development of the research question from the claim • a specific and relevant research question • selection of sufficient and relevant sources • appropriate use of genre conventions • acknowledgment of sources of information through appropriate use of referencing conventions	4–5
• a reasonable rationale that links the research question and the claim • a relevant research question • selection of relevant sources • use of basic genre conventions • use of basic referencing conventions	2–3
• a vague or irrelevant rationale for the investigation • an inappropriate research question • selection of insufficient or irrelevant sources • inadequate use of genre conventions • inadequate acknowledgment of sources.	1
The student response does not match any of the descriptors above.	0

Analysing	Marks
The student response has the following characteristics:	
• the identification of sufficient and relevant evidence • thorough identification of relevant trends/patterns/relationships in evidence • thorough and appropriate identification of limitations of evidence	4–5
• the identification of relevant evidence • identification of obvious trends/patterns/relationships in evidence • basic identification of limitations of evidence	2–3
• the identification of insufficient and irrelevant evidence • identification of incorrect or irrelevant trends/patterns/relationships in evidence • incorrect or insufficient identification of limitations of evidence.	1
The student response does not match any of the descriptors above.	0

Interpreting	Marks
The student response has the following characteristics:	
• justified scientific argument/s • justified conclusion linked to the research question • fluent and concise use of scientific language/representations	4–5
• reasonable scientific argument/s • reasonable conclusion relevant to the research question • competent use of scientific language/representations	2–3
• inappropriate or irrelevant argument/s • inappropriate or irrelevant conclusion • incorrect use of language/representations.	1
The student response does not match any of the descriptors above.	0

Evaluating	Marks
The student response has the following characteristics:	
• justified discussion of the quality of evidence • extrapolation of credible findings of the research to the claim • suggested improvements and extensions to the investigation that are considered and relevant to the claim	4–5
• reasonable description of the quality of evidence • application of relevant findings of the research to the claim • suggested improvements and/or extensions to the investigation that are relevant to the claim	2–3
• cursory or simplistic statements about the quality of evidence • application of insufficient or inappropriate findings of the research to the claim • ineffective or irrelevant suggestions.	1
The student response does not match any of the descriptors above.	0

External assessment: Examination — combination response (50%)

External assessment is developed and marked by the QCAA. The external assessment in Physics is common to all schools and administered under the same conditions, at the same time, on the same day.

Assessment objectives

1. Describe ideas and findings about gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model.
2. Apply understanding of gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model.
3. Analyse data about gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model to identify trends, patterns, relationships, limitations or uncertainty.
4. Interpret evidence about gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model to draw conclusions based on analysis.

Specifications

This examination:

- includes two papers. Each paper consists of a number of different types of questions relating to Units 3 and 4
- may ask students to respond using
  - multiple choice
  - single words
  - sentences or paragraphs
- may ask students to
  - calculate using algorithms
  - interpret unseen stimulus, including graphs, tables or diagrams.

Conditions

Paper 1

- Mode: written
- Time allowed
  - Perusal time: 5 minutes
  - Working time: 90 minutes
- Students may use a QCAA-approved graphics or scientific calculator.
- The QCAA provides the QCAA Physics formula and data book.

Paper 2

- Mode: written
- Time allowed
  - Perusal time: 5 minutes
  - Working time: 90 minutes
- Students may use a QCAA-approved graphics or scientific calculator.
- The QCAA provides the QCAA Physics formula and data book.

Glossary

The syllabus glossary is available at www.qcaa.qld.edu.au/downloads/senior-qce/common/snr_glossary_cognitive_verbs.pdf.

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Version history

Version	Date of change	Information
1.0	January 2024	Released for familiarisation and planning (with implementation starting in 2025)
1.1	July 2024	Released for implementation with minor updates
1.2	October 2024	ISBN removed and minor updates