Physics 2019 v1.3

General Senior Syllabus

This syllabus is for implementation with Year 11 students in 2019.

Queensland Government
Queensland Curriculum & Assessment Authority
220808

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1 Course overview

1.1 Introduction

1.1.1 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.

Assumed knowledge, prior learning or experience

The P–10 Australian Curriculum: Science is assumed knowledge for this syllabus.

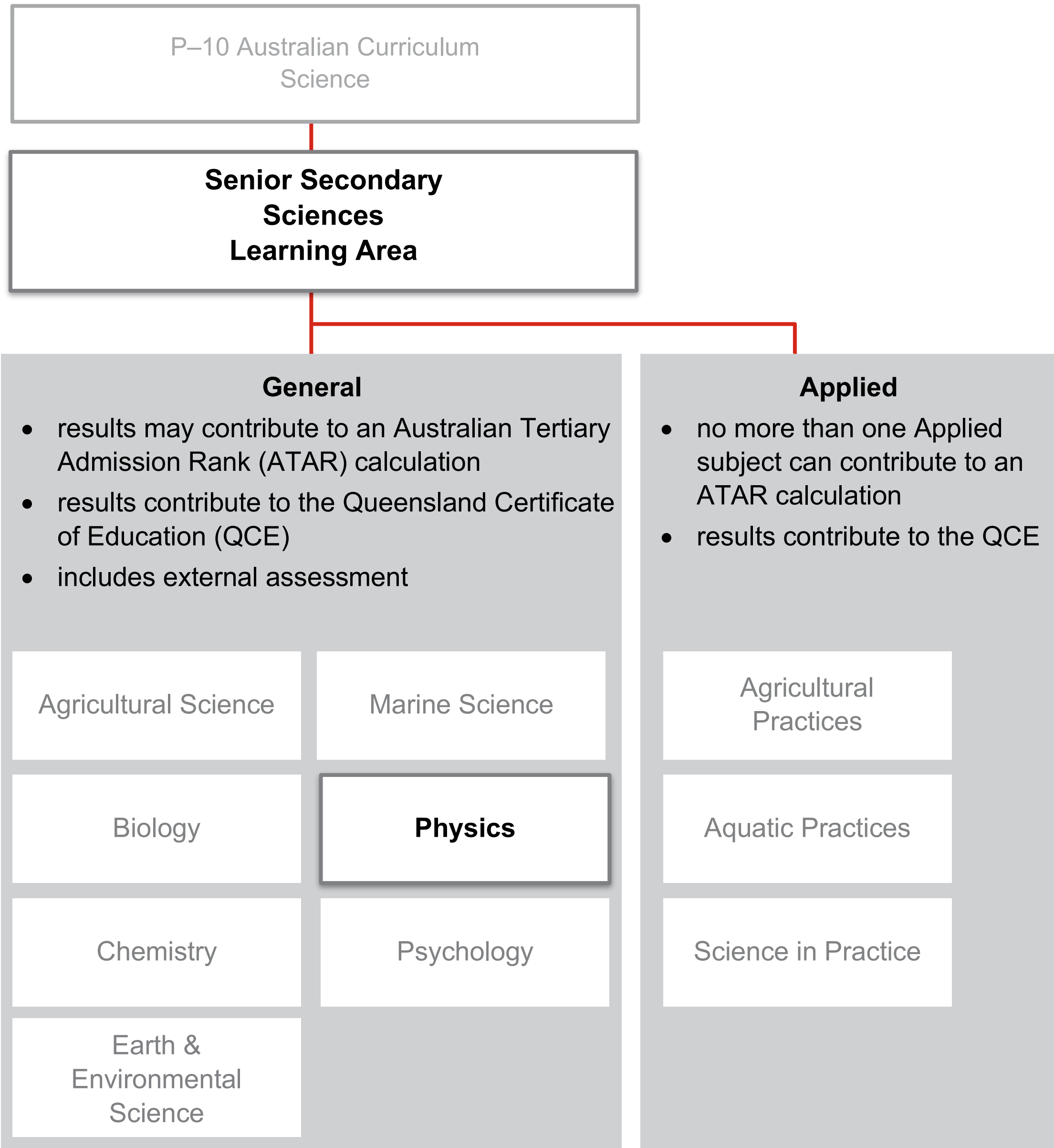
Pathways

Physics is a General subject suited to students who are interested in pathways beyond school that lead to tertiary studies, vocational education or work. A course of study in Physics can establish a basis for further education and employment in the fields of science, engineering, medicine and technology.

1.1.2 Learning area structure

All learning areas build on the P–10 Australian Curriculum.

Figure 1: Learning area structure



1.1.3 Course structure

Physics is a course of study consisting of four units. Subject matter, learning experiences and assessment increase in complexity from Units 1 and 2 to Units 3 and 4 as students develop greater independence as learners.

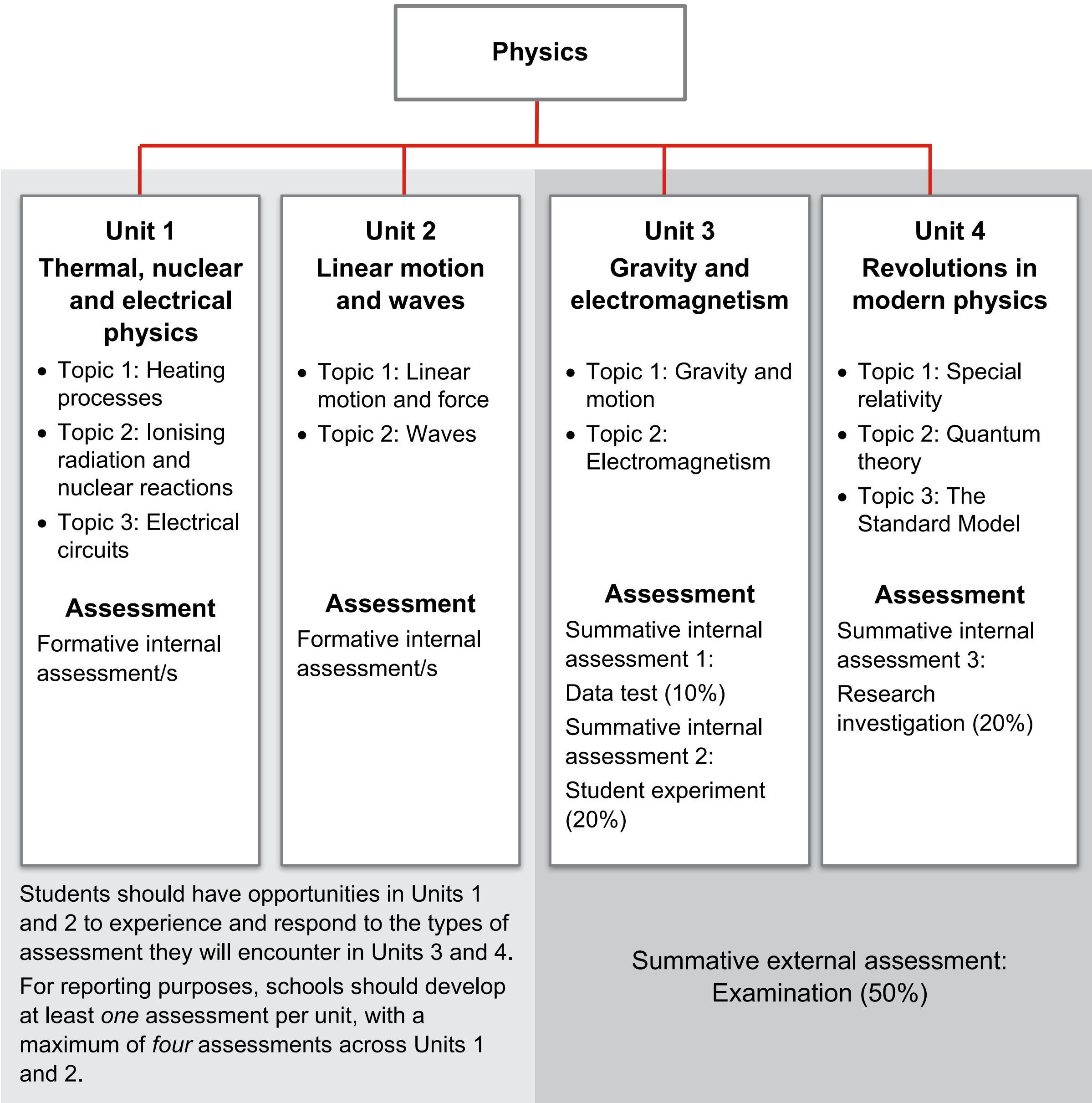
Units 1 and 2 provide foundational learning, which allows students to experience all syllabus objectives and begin engaging with the course subject matter. Students should complete Units 1 and 2 before beginning Units 3 and 4.

Units 3 and 4 consolidate student learning. Only the results from Units 3 and 4 will contribute to ATAR calculations.

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

Figure 2 outlines the structure of this course of study.

Figure 2: Course structure



1.2 Teaching and learning

1.2.1 Syllabus objectives

The syllabus objectives outline what students have the opportunity to learn. Assessment provides evidence of how well students have achieved the objectives.

Syllabus objectives inform unit objectives, which are contextualised for the subject matter and requirements of the unit. Unit objectives, in turn, inform the assessment objectives, which are further contextualised for the requirements of the assessment instruments. The number of each objective remains constant at all levels, i.e. Syllabus objective 1 relates to Unit objective 1 and to Assessment objective 1 in each assessment instrument.

Syllabus objectives are described in terms of actions that operate on the subject matter. Students are required to use a range of cognitive processes in order to demonstrate and meet the syllabus objectives. These cognitive processes are described in the explanatory paragraph following each objective in terms of four levels: retrieval, comprehension, analytical processes (analysis), and knowledge utilisation, with each process building on the previous processes (see Marzano & Kendall 2007, 2008). That is, comprehension requires retrieval, and knowledge utilisation requires retrieval, comprehension and analytical processes (analysis).

By the conclusion of the course of study, students will:

Syllabus objective	Unit 1	Unit 2	Unit 3	Unit 4
1. describe and explain scientific concepts, theories, models and systems and their limitations	•	•	•	•
2. apply understanding of scientific concepts, theories, models and systems within their limitations	•	•	•	•
3. analyse evidence	•	•	•	•
4. interpret evidence	•	•	•	•
5. investigate phenomena	•	•	•	•
6. evaluate processes, claims and conclusions	•	•	•	•
7. communicate understandings, findings, arguments and conclusions.	•	•	•	•

1. describe and explain scientific concepts, theories, models and systems and their limitations

When students describe and explain scientific concepts, theories, models and systems and their limitations, they give a detailed account of a concept, theory, model or system making relationships, reasons or causes evident. They reflect on relevant social, economic, ethical and cultural factors.

2. apply understanding of scientific concepts, theories, models and systems within their limitations

When students apply their understanding of scientific concepts, theories, models and systems within their limitations, they explain local, regional and global phenomena and determine outcomes, behaviours and implications. They use algebraic, visual and graphical representations of scientific relationships and data to determine unknown scientific quantities or variables. They recognise the limitations of models and theories when discussing results.

3. **analyse evidence**

   When students analyse evidence, they recognise the variety of forms of evidence, and distinguish between quantitative, qualitative, primary and secondary evidence. When students analyse evidence in the form of qualitative data, they identify the essential elements, features or components of the data. When students analyse evidence in the form of quantitative data, they use mathematical processes to identify trends, patterns, relationships, limitations and uncertainty in the data.

4. **interpret evidence**

   When students interpret evidence, they use their knowledge and understanding of scientific concepts, theories, models and systems and their limitations to draw conclusions based on their analysis of qualitative and quantitative evidence and established criteria.

5. **investigate phenomena**

   When students investigate phenomena, they plan and carry out experimental and/or research activities in order to obtain evidence for the purpose of reaching a conclusion. They collect, collate and process evidence. Students ensure that relevant ethical, environmental and safety considerations have been incorporated into their practice.

6. **evaluate processes, claims and conclusions**

   When students evaluate processes, claims and conclusions, they critically reflect on the available evidence and make judgments about its application to a research question, and its use to inform further investigation. When students evaluate processes, they use the quality of the evidence to evaluate the validity and reliability of the method used, the appropriateness of assumptions made and possible refinements required. When students evaluate claims, they identify the evidence that would be required to support or refute the claim. They scrutinise evidence for bias, conjecture, alternatives or inaccuracies. When students evaluate conclusions, they consider the credibility of the supporting evidence.

7. **communicate understandings, findings, arguments and conclusions**

   When students communicate, they use scientific representations and language within appropriate genres to present information. They use technology to share knowledge by exchanging information and creating information products.

1.2.2 Underpinning factors

There are three skill sets that underpin senior syllabuses and are essential for defining the distinctive nature of subjects:

- literacy — the set of knowledge and skills about language and texts essential for understanding and conveying Physics 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 skill sets, which overlap and interact, are derived from current education, industry and community expectations. They encompass the knowledge, skills, capabilities, behaviours and dispositions that will help students live and work successfully in the 21st century.

Together these three skill sets shape the development of senior subject syllabuses. Although coverage of each skill set may vary from syllabus to syllabus, students should be provided with opportunities to learn through and about these skills over the course of study. Each skill set contains identifiable knowledge and skills that can be directly assessed.

Literacy in Physics

The skills of literacy in science (distinct from 'scientific literacy') are essential for successful scientific inquiry (Douglas et al. 2006, Saul 2004, Yore et al. 2003). In any scientific inquiry activity, literacy skills support students by enabling them to grapple with ideas, conduct research, discuss their thoughts, enhance conceptual understanding and solve problems (Krajcik & Southerland 2010).

The literacy skills important to this subject are those related to the comprehension and composition of texts that provide information, describe and explain events and phenomena, report on experiments, present and analyse data, and offer opinions or claims (ACARA 2015a). Physics students comprehend and compose multimedia texts, such as reports, charts, graphs, diagrams, pictures, maps, animations, models and other visual media. They understand and apply language structures that are used to link information and ideas, give descriptions and explanations, formulate research questions and construct evidence-based arguments capable of expressing an informed position (ACARA 2015a).

Students learn these skills by having opportunity to engage with:

- rich and varied science and media texts
- class activities that use literacy as a tool for learning
- strategies for reading scientific texts (Moore 2009).

The learning opportunities described above can be integrated with stimulus questions, Science as a Human Endeavour (SHE) subject matter and mandatory practicals. Students could be asked to:

- explain links between new ideas and prior knowledge and experiences
- engage in learning experiences directed by a question that is meaningful to their lives
- connect multiple representations of a concept (e.g. written texts, formulas, graphs or diagrams of the same concept)
- use scientific ideas to compose evidence-based conclusions in the mandatory practicals
- engage with the discourses of science such as those found in scientific literature and media texts (Krajcik & Southerland 2010).

These strategies will promote students' ability to read, write and communicate about science so that they can engage with science-related issues throughout their lives.

These aspects of literacy knowledge and skills are embedded in the syllabus objectives, unit objectives and subject matter, and instrument-specific marking guides (ISMGs) for Physics.

Numeracy in Physics

The skills of numeracy in Physics are essential for successful scientific inquiry. In any scientific inquiry activity, numeracy skills support students by enabling them to make and record observations; order, represent and analyse data; and interpret trends and relationships (ACARA 2015b).

The numeracy skills important to this subject are those related to the interpretation of complex spatial and graphical representations, and the appreciation of the ways in which scientific concepts, theories, systems and models are structured, communicated, interact or change across spatial and temporal scales (ACARA 2015b). Students will use knowledge and skills in areas such as:

- graphing
- ratio and proportion
- converting from one unit to another
- scientific notation
- an understanding of place in number (significant figures)
- estimation and calculation in order to analyse data
- determining the reliability of data
- interpreting and manipulating mathematical relationships in order to calculate and predict values (ACARA 2009, 2015).

Students will learn these skills as they:

- measure and record data during the mandatory practicals
- use or interpret meaning from formulas
- interpret graphical information presented in science and media texts
- undertake class activities that use numeracy as a tool for learning
- use mathematics or equations as justification or evidence for conclusions
- interpret and represent information in a variety of forms.

These opportunities will promote students' ability to develop and use numeracy skills in Physics.

These aspects of numeracy knowledge and skills are embedded in the syllabus objectives, unit objectives and subject matter, and ISMGs for Physics.

21st century skills

The 21st century skills identified in the following table reflect a common agreement, both in Australia and internationally, on the skills and attributes students need to prepare them for higher education, work and engagement in a complex and rapidly changing world.

21st century skills	Associated skills	21st century skills	Associated skills
critical thinking	• analytical thinking • problem-solving • decision-making • reasoning • reflecting and evaluating • intellectual flexibility	creative thinking	• innovation • initiative and enterprise • curiosity and imagination • creativity • generating and applying new ideas • identifying alternatives • seeing or making new links
communication	• effective oral and written communication • using language, symbols and texts • communicating ideas effectively with diverse audiences	collaboration and teamwork	• relating to others (interacting with others) • recognising and using diverse perspectives • participating and contributing • community connections
personal and social skills	• adaptability/flexibility • management (self, career, time, planning and organising) • character (resilience, mindfulness, open- and fair-mindedness, self-awareness) • leadership • citizenship • cultural awareness • ethical (and moral) understanding	Information & communication technologies (ICT) skills	• operations and concepts • accessing and analysing information • being productive users of technology • digital citizenship (being safe, positive and responsible online)

Physics helps develop the following 21st century skills:

- critical thinking
- creative thinking
- communication
- collaboration and teamwork
- personal and social skills
- information & communication technologies (ICT) skills.

These elements of 21st century skills are embedded in the syllabus objectives, unit objectives and subject matter, and ISMGs for Physics.

1.2.3 Aboriginal perspectives and Torres Strait Islander perspectives

The QCAA is committed to reconciliation in Australia. 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.

1.2.4 Pedagogical and conceptual frameworks

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**.

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.

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 science inquiry (Tytler 2007). This expectation can be seen, for example, in the inclusion of the mandatory practicals, student experiment and research investigation.

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 2015c).

It is expected that students are taught science inquiry skills (Krajcik et al. 2000). The syllabus outlines a number of these skills in the subject matter. Some science inquiry skills will be used to complete the mandatory and suggested practicals. 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 decide how the science inquiry skills are to be developed. For example, teachers will determine how mandatory practicals 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.

Framework to describe the inquiry process

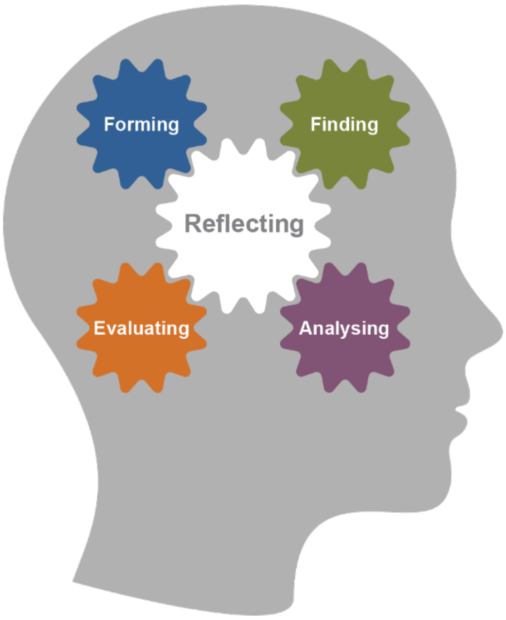
In order to support student engagement in activities involving inquiry, it is useful to establish a common language or framework to distinguish between stages of the process.

The stages involved in any inquiry are:

- forming and describing the inquiry activity
- finding valid and reliable evidence for the inquiry activity
- analysing and 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 3: Stages of inquiry process



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* provides guidance about current science safety protocols.

It is the responsibility of all schools to ensure that their practices meet current legislation requirements. References to relevant legislation and regulations are supported by the Reference list located on the Physics subject page of the QCAA website.

1.2.5 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 Physics. It is particular to each unit in the course of study and provides the basis for student learning experiences.

Subject matter has a direct relationship to the unit objectives, but is of a finer granularity and is more specific. These statements of learning are constructed in a similar way to objectives. Each statement:

- describes an action (or combination of actions) — what the student is expected to do
- describes the element — expressed as information, mental procedures and/or psychomotor procedures
- is contextualised for the topic or circumstance particular to the unit.

Organisation of subject matter

The subject matter is organised as topics within each unit.

The subject matter indicates the required knowledge and skills that students must acquire. Students should experience the mandatory practicals.

The subject matter from Units 3 and 4 will be assessed by the external examination.

Science as a Human Endeavour

Each Queensland senior Science subject requires students to learn and apply aspects of the knowledge and skill of the discipline. 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 will not be 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 Science as a Human Endeavour (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 guidance in each topic. This highlights opportunities for teachers to contextualise the associated subject matter and provides stimulus for the development of claims and research questions for investigation.

Additional opportunities include:

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

Finally, the SHE statements at the end of each topic may be used to support the development and interrogation of claims, and be useful as a starting point for the research investigation.

Guidance

The guidance included with each topic is designed to clarify the scope of the subject matter and identify opportunities to integrate science inquiry skills and SHE strands into the subject matter. A number of tags are used to highlight aspects of the guidance:

- **Notional time:** the depth of subject matter coverage is indicated by the amount of time needed to cover this subject matter in the sequence presented in the syllabus.
- **Formula:** defines a formula described in the subject matter.
- **SHE:** identifies an opportunity to integrate an aspect of the Science as a Human Endeavour strand and may also be used as a starting point for a research investigation.
- **Suggested practical:** identifies an opportunity for inquiry skills to be developed and may be used as a starting point for a student experiment.
- **Stimulus questions:** identifies a question that could be used to stimulate student interest or as the starting point for a research investigation.
- **Syllabus links:** identifies links to prior learning.

1.3 Assessment — general information

Assessments are formative in Units 1 and 2, and summative in Units 3 and 4.

Assessment	Unit 1	Unit 2	Unit 3	Unit 4
Formative assessments	●	●		
Summative internal assessment 1			●	
Summative internal assessment 2			●	
Summative internal assessment 3				●
Summative external assessment			●	●

1.3.1 Formative assessment — Units 1 and 2

Formative assessments provide feedback to both students and teachers about each student’s progress in the course of study.

Schools develop internal assessments for each senior subject based on the learning described in Units 1 and 2 of the subject syllabus. Each unit objective must be assessed at least once.

For reporting purposes, schools should devise at least *two* but no more than *four* assessments for Units 1 and 2 of this subject. At least *one* assessment must be completed for *each* unit.

The sequencing, scope and scale of assessments for Units 1 and 2 are matters for each school to decide and should reflect the local context.

Teachers are encouraged to use the A–E descriptors in the reporting standards (Section 1.4) to provide formative feedback to students and to report on progress.

1.3.2 Summative assessments — Units 3 and 4

Students will complete a total of *four* summative assessments — three internal and one external — that count towards their final mark in each subject.

Schools develop *three* internal assessments for each senior subject, based on the learning described in Units 3 and 4 of the syllabus.

The three summative internal assessments will be endorsed and the results confirmed by the QCAA. These results will be combined with a single external assessment developed and marked by the QCAA. The external assessment results for Physics will contribute 50% towards a student's result.

Summative internal assessment — instrument-specific marking guides

This syllabus provides ISMGs for the three summative internal assessments in Units 3 and 4.

The ISMGs describe the characteristics evident in student responses and align with the identified assessment objectives. Assessment objectives are drawn from the unit objectives and are contextualised for the requirements of the assessment instrument.

Criteria

Each ISMG groups assessment objectives into criteria. An assessment objective may appear in multiple criteria or in a single criterion of an assessment.

Making judgments

Assessment evidence of student performance in each criterion is matched to a performance-level descriptor, which describes the typical characteristics of student work.

Where a student response has characteristics from more than one performance level, a best-fit approach is used. Where a performance level has a two-mark range, it must be decided if the best fit is the higher or lower mark of the range.

Authentication

Schools and teachers must have strategies in place for ensuring that work submitted for internal summative assessment is the student's own. Authentication strategies outlined in QCAA guidelines, which include guidance for drafting, scaffolding and teacher feedback, must be adhered to.

Summative external assessment

The summative external assessment adds valuable evidence of achievement to a student's profile. External assessment is:

- common to all schools
- administered under the same conditions at the same time and on the same day
- developed and marked by the QCAA according to a commonly applied marking scheme.

The external assessment contributes 50% to the student's result in Physics. It is not privileged over the school-based assessment.

1.4 Reporting standards

Reporting standards are summary statements that succinctly describe typical performance at each of the five levels (A–E). They reflect the cognitive taxonomy and objectives of the course of study.

The primary purpose of reporting standards is for twice-yearly reporting on student progress. These descriptors can also be used to help teachers provide formative feedback to students and to align ISMGs.

Reporting standards

A
The student accurately describes and explains 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 accurately applies understanding of scientific concepts, theories, models and systems within their limitations to explain a variety of phenomena, and predict outcome/s, 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 evidence 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 investigates phenomena by carrying out effective experiments and research investigations. They efficiently collect, collate and process relevant evidence. They critically evaluate processes, claims and conclusions by insightfully scrutinising evidence, extrapolating credible findings, and discussing the reliability and validity of experiments. The student communicates effectively by using scientific representations and language accurately and concisely within appropriate genres.

B
The student accurately describes and explains 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 accurately applies understanding of scientific concepts, theories, models and systems within their limitations to explain phenomena and predict outcome/s, 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 evidence by effectively 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 investigates phenomena by carrying out effective experiments and research investigations. They collect, collate and process relevant evidence. They evaluate processes, claims and conclusions by scrutinising evidence, applying relevant findings and discussing the reliability and validity of experiments. The student communicates accurately by using scientific representations and language within appropriate genres to present information.

C
The student describes and explains 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 applies their understanding of scientific concepts, theories, models and systems within their limitations to explain phenomena and predict outcome/s, 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 evidence 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 investigates phenomena by carrying out experiments and research investigations. They collect, collate and process evidence. They evaluate processes, claims and conclusions by describing the quality of evidence, applying findings, and describing the reliability and validity of experiments. The student communicates using scientific representations and language within appropriate genres to present information.
D
The student describes and gives accounts of aspects of concepts, theories, models and systems. They use rudimentary representations of scientific relationships or data to determine unknown scientific quantities or variables. The student analyses evidence 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 carries out aspects of experiments and research investigations. They discuss processes, claims or conclusions. They consider the quality of evidence and conclusions. The student uses scientific representations or language to present information.
E
The student describes scenarios and refers 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. The student communicates information.

2 Unit 1: Thermal, nuclear and electrical physics

2.1 Unit description

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.

2.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

1. describe and explain 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 evidence 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. investigate phenomena associated with heating processes, ionising radiation and nuclear reactions, and electrical circuits
6. evaluate processes, claims and conclusions about heating processes, ionising radiation and nuclear reactions, and electrical circuits
7. communicate understandings, findings, arguments and conclusions about heating processes, ionising radiation and nuclear reactions, and electrical circuits.

2.3 Topic 1: Heating processes

In this topic, students will:

Subject matter	Guidance
Kinetic particle model and heat flow • describe the kinetic particle model of matter • define and distinguish between thermal energy, temperature, kinetic energy, heat and internal energy • explain heat transfers in terms of conduction, convection and radiation.	• **Notional time:** 2 hours • **Stimulus questions** – What is heat? – What is the difference between heat and temperature?
Temperature and specific heat capacity • use $T_K = T_C + 273$ to convert temperature measurements between Celsius and Kelvin • 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 • explain that a change in temperature is due to the addition or removal of energy from a system (without phase change) • define *specific heat capacity* and the concept of proportionality • interpret tabulated and graphical data of heat added to a substance and its subsequent temperature change (without phase change) • solve problems involving specific heat capacity. • **Mandatory practicals** – Conduct an experiment that obtains data to be plotted on a scatter graph (with correct title and symbols, units and labels on the axes), analysed by calculating the equation of a linear trend line, interpreted to draw a conclusion, and reported on using scientific conventions and language. – Conduct an experiment that determines the specific heat capacity of a substance, ensuring that measurement uncertainties associated with mass and temperature are propagated. Where the mean is calculated (in this, and future experiments), determine the percentage and/or absolute uncertainty of the mean.	• **Notional time:** 6 hours • **Stimulus questions** – Why is it important to have the same unit of measurement internationally? – Which has more energy — a cup of coffee or a swimming pool? – What property of water makes it ideal for use as a coolant in car engines? • Students do not need to use mathematical formulas relating temperature and the average kinetic energy of the particles. • **Suggested practicals** – Conduct an experiment to investigate the precision and accuracy of different temperature measuring devices, such as analogue and digital thermometers by determining measurement uncertainty. – Conduct an experiment to investigate the proportional relationship between heat and temperature change. – Conduct an experiment to investigate the initial and final temperature of two liquids before and after they are mixed. Compare the final temperature data with a temperature value calculated theoretically by finding the percentage error. • **Formulas:** $T_K = T_C + 273$ $Q = mc\Delta T$ • **SHE:** Students could explore the development of temperature scales, e.g. Fahrenheit, Celsius and Kelvin.

Subject matter	Guidance
Phase changes and specific latent heat • explain why the temperature of the system remains the same during the process of state change; explain it in terms of the internal energy of a system and the kinetic particle model of matter • define *specific latent heat* • solve problems involving specific latent heat.	• **Notional time:** 4 hours • **Stimulus questions** – Why do you feel colder when you are wearing wet clothes? – How is it possible to boil water in a paper cup on a camp fire? • **Suggested practical:** Conduct an experiment to observe the change in temperature while heating substances before, during and after a phase change. • **Formula:** $Q = mL$
Energy conservation in calorimetry • define *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 this as the zeroth law of thermodynamics • solve problems involving specific heat capacity, specific latent heat and thermal equilibrium.	• **Notional time:** 4 hours • **Stimulus question:** Does putting a coat on a snowman make it melt faster?
Energy in systems — mechanical work and efficiency • explain that a system with thermal energy has the capacity to do mechanical work • recall 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 that 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 • define *efficiency* • solve problems involving finding the efficiency of heat transfers.	• **Notional time:** 2 hours • **Stimulus question:** If useable energy is reduced every time an energy transfer occurs, what implications will this have on the availability of useable energy in the future? • **Formulas:** $\Delta U = Q + W$ $\eta = \frac{\text{energy output}}{\text{energy input}} \times \frac{100}{1}\%$ • **SHE:** Students could use the concepts of energy transfers and efficiency to consider the economic and ethical implications of this science on the choice of solar panel, building design, flooring insulation, etc.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Energy security and sustainability — emerging energy sources:** The science of heating processes is of key importance to the development of efficient and cost-effective technologies that use sustainable and renewable

Subject matter	Guidance
	energy sources. • **Energy balance of Earth:** Predicting global temperatures and human-induced climate change is greatly aided by new technologies and an understanding of heating processes. • **Development of thermodynamics:** The need to increase 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).

2.4 Topic 2: Ionising radiation and nuclear reactions

In this topic, students will:

Subject matter	Guidance
Nuclear model and stability • describe the nuclear model of the atom characterised by a small nucleus surrounded by electrons • explain why protons in the nucleus repel each other • define 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.	• **Notional time:** 2 hours • Students are not required to identify the Bohr (or other historical) model of the atom at this stage. • Students should use the ${}^{A}_{Z}\mathrm{X}$ nomenclature. • **SHE:** Students could know that the development of models of the atom often required a wide range of evidence from multiple individuals and across disciplines.
Spontaneous decay and half-life • explain natural radioactive decay in terms of stability • define *alpha radiation*, *beta positive radiation*, *beta negative radiation* and *gamma radiation* • 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 protons, neutrons or mass in a nucleus can result in alpha, beta positive and beta negative decay • solve problems involving balancing nuclear equations	• **Notional time:** 6 hours • Students are not expected to give reasons for the presence of an electron neutrino or electron antineutrino in the relevant decay equations. • Students are not required to demonstrate an understanding of exponential decay in the form e^{-kt}. However, students should be able to recognise exponential decay graphs and know that each species of radionuclide has a specific half-life. They should be able to use these graphs to estimate half-lives. • **Suggested practical:** Conduct an experiment or simulation investigating

Subject matter	Guidance
• represent spontaneous alpha, beta positive and beta negative decay using decay equations, e.g. $^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}^{2+} + \gamma$ $^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{28}\mathrm{Ni} + {}^{0}_{-1}e + \bar{\nu}_e + \gamma$ $^{102}_{50}\mathrm{Sn} \rightarrow {}^{102}_{49}\mathrm{In} + {}^{0}_{+1}e + \nu_e + \gamma$ • explain how a radionuclide will, through a series of spontaneous decays, become a stable nuclide • define *half-life* • solve radioactive decay problems involving whole numbers of half-lives.	shielding effects and/or the relationship between intensity and distance from a radioactive source. • **Formula:** $N = N_o(\frac{1}{2})^n$ • **SHE:** Students could explore – how advances in scientists' understanding of the properties of nuclear radiation have influenced medical treatment and imaging – the use of scientific knowledge to predict beneficial and/or harmful or unintended consequences, e.g. choosing appropriate radioisotopes for medical imaging, carefully storing nuclear waste – how scientific knowledge of radioactive decay can enable scientists to offer valid explanations and make reliable predictions in radiometric dating of materials.
Energy and mass defect • describe energy in terms of electron volts (eV) and joules (J) • define *artificial transmutation* • distinguish between artificial transmutations and natural radioactive decay • define *nuclear fission* • explain a neutron-induced nuclear fission reaction, including references to extra neutrons produced from many of these reactions • research nuclear safety, considering the suitability of using the sources of information in terms of their credibility • explain a fission chain reaction • define *nuclear fusion* • define *mass defect*, *binding energy* and *binding energy per nucleon* • recall Einstein's mass–energy equivalence relationship • solve problems involving Einstein's mass–energy equivalence relationship • 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.	• **Notional time:** 5 hours • Students should represent nuclear fission with nuclear equations similar to spontaneous decay equations, e.g. $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{92}_{36}\mathrm{Kr} + {}^{141}_{56}\mathrm{Ba} + 3\,{}^{1}_{0}\mathrm{n}$ + energy • A specific example of a fission chain reaction is not required in the explanation. • Students could represent nuclear fusion with nuclear equations, e.g. $^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$ + energy. • **Formula:** $\Delta E = \Delta mc^2$ • **Stimulus question:** Should Australia generate power using nuclear fission? • **SHE:** Students could explore the possibility of nuclear fission-based power production replacing fossil fuels to generate electricity.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a	• **Radioisotopes and radiometric dating:** An understanding of nuclear processes has led to the use of new analytical tools (e.g. radiometric dating) to

Subject matter	Guidance
research investigation.	understand past events. • **Harnessing nuclear power:** The health and environmental risks associated with the use of nuclear fission must be considered along with the environmental and cost benefits of lowering fossil fuel consumption. • **Nuclear fusion in stars:** 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.

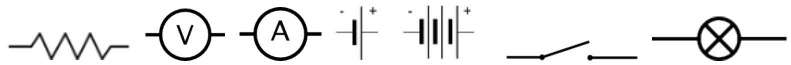
2.5 Topic 3: Electrical circuits

In this topic, students will:

Subject matter	Guidance
Current, potential difference and energy flow • recall that electric charge can be positive or negative • recall that electric current is carried by discrete electric charge carriers • recall the law of conservation of electric charge • recall that electric charge is conserved at all points in an electrical circuit and recognise this as Kirchhoff's current law • define *electric current*, *electrical potential difference* in a circuit, and *power* • solve problems involving electric current, electric charge and time • explain that the energy inputs in a circuit equal the sum of energy output from loads in the circuit and recognise this as Kirchhoff's voltage law • recall that the energy available to electric charges moving in an electrical circuit is measured using electrical potential difference • solve problems involving electrical potential difference • explain why electric charge separation produces an electrical potential difference (no calculations required to demonstrate this) • solve problems involving power.	• **Notional time:** 4 hours • **Syllabus link:** Students should be able to recall the existence of electrons as negatively charged particles and protons as positively charged particles, and use the concept of electrostatic repulsion (Unit 1 Topic 2: Ionising radiation and nuclear reactions). • **Formulas:** $I = \frac{q}{t}$ $V = \frac{W}{q}$ $P = \frac{W}{t}$ • **SHE:** Students could explore how – 'conventional current' has been accepted as the international convention; consistent use now ensures clear communication of ideas and findings across the globe – increases in the use of household electrical devices during extreme weather (heat in Australian summers or cold in European winters) creates supply problems causing brownouts and power failures.

Subject matter	Guidance

Resistance
• define *resistance*
• recall and solve problems using Ohm's Law
• compare and contrast ohmic and non-ohmic resistors
• interpret graphical representations of electrical potential difference versus electric current data to find resistance using the gradient and its uncertainty.
• **Mandatory practical:** Conduct an experiment that measures electric current through, and electrical potential difference across an ohmic resistor in order to find resistance.
  – Write a research question.
  – Suggest modifications to the methodology used in class to improve the outcome.
  – Collect sufficient data.
  – Consider safety and manage risks.
	• **Notional time:** 4 hours
	• Students should be able to recognise the characteristics of ohmic and non-ohmic resistors in terms of the gradient of an electrical potential difference – electric current graph. For ohmic resistors, students should be able to determine the resistance from the gradient.
	• **Suggested practical:** Conduct an experiment to compare ohmic and non-ohmic resistors.
	• **Formula:** $R = \frac{V}{I}$

Circuit analysis and design
• define *power dissipation* over resistors in a circuit
• solve problems involving electrical potential difference, electric current, resistance and power
• recall resistor, voltmeter, ammeter, cell, battery, switch and bulb circuit diagram symbols
• recognise 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
• design simple series, parallel and series/parallel circuits.
	• **Notional time:** 6 hours.
	• Students should be able to recognise and draw the following symbols.
	
	• **Suggested practicals**
	  – Conduct an experiment to investigate series and parallel circuits.
	  – Conduct an experiment to design and build simple circuits for specific 'real-life' purposes.
	• **Formulas:** $P = VI$
	$P = I^2R$
	$V_t = V_1 + V_2 + \cdots V_n$
	$R_t = R_1 + R_2 + \cdots R_n$
	$I_t = I_1 + I_2 + \cdots I_n$
	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \frac{1}{R_n}$
	• **Syllabus link:** Students should be able to integrate the concepts of circuit design, power dissipation, thermodynamics and efficiency to investigate the use of electricity in heating elements.

Subject matter	Guidance
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Electrical energy in the home:** Developing new household electrical devices, improving the efficiency of existing devices and ensuring consistency of electrical standards all require international cooperation between scientists, engineers and manufacturers. • **Powering the digital age:** Computers, smartphones and the internet have changed the world, but none would be possible without a reliable supply of electricity. • **Electric lighting:** Concerns about sustainable energy usage and global warming have led to international research and development to improve the energy efficiency of electric lighting.

2.6 Assessment guidance

In constructing assessment instruments for Unit 1, schools should ensure that the objectives cover, or are chosen from, the unit objectives. If one assessment instrument is developed for a unit, it must assess all the unit objectives; if more than one assessment instrument is developed, the unit objectives must be covered across those instruments.

It is suggested that student performance on Unit 1 is assessed using techniques modelled on the techniques used in Unit 4:

- a research investigation
- an examination that includes some items modelled on the data test.

3 Unit 2: Linear motion and waves

3.1 Unit description

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.

3.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

1. describe and explain linear motion and force, and waves
2. apply understanding of linear motion and force, and waves
3. analyse evidence about linear motion and force, and waves
4. interpret evidence about linear motion and force, and waves
5. investigate phenomena associated with linear motion and force, and waves
6. evaluate processes, claims and conclusions about linear motion and force, and waves
7. communicate understandings, findings, arguments and conclusions about linear motion and force, and waves.

3.3 Topic 1: Linear motion and force

In this topic, students will:

Subject matter	Guidance
Vectors • define the terms *vector* and *scalar*, and use these terms to categorise physical quantities, e.g. velocity and speed • calculate resultant vectors through the addition and subtraction of two vectors in one dimension.	• **Notional time:** 4 hours • **Stimulus question:** If I start in the middle of the oval and walk 100 metres, where could I end up? • Vectors could be represented in the following ways: F, $\tilde{F}$ and $\vec{F}$ $\longrightarrow$ • Students should recognise that quantities that do not require a direction to complete their definition, such as energy, are scalars.

Linear motion
• define the terms *displacement*, *velocity* and *acceleration*
• compare and contrast instantaneous and average velocity
• describe the motion of an object by interpreting a linear motion graph
• calculate and interpret the intercepts and gradients (and their uncertainties) of displacement–time and velocity–time graphs, and the areas under velocity–time and acceleration–time graphs
• solve problems involving the equations of uniformly accelerated motion in one dimension
• recall that the acceleration due to gravity is constant near the Earth's surface.
• **Mandatory practical:** Conduct an experiment to verify the value of acceleration due to gravity on the Earth's surface. *All* data sets that suggest a non-linear relationship, data (e.g. t^2 versus s) should be linearised and plotted, allowing for the calculation of the equation of a linear trend line. An evaluation of the experimental process undertaken, and of the conclusions drawn, will require students to
  – discuss the reliability and validity of the experimental process with reference to the uncertainty and limitations of the data
  – identify justifiable sources of imprecision and inaccuracy
  – suggest improvements or extensions to the experiment using the uncertainty and limitations identified.
• **Mandatory practical:** Conduct an experiment that requires students to
	• **Notional time:** 6 hours
	• **Stimulus question:** The hare and the tortoise — how is it that the slow-moving tortoise beat the faster hare?
	• Areas under graphs should be found using simple geometry, not calculus.
	• Students should be able to determine average velocity using a graph and an equation. However, students only need to determine instantaneous velocity for linear graphs or using an equation.
	• Students should use $g = 9.8\, m\, s^{-2}$ as the accepted value.
	• **Formulas:** $v = u + at$
	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$

Subject matter	Guidance
construct and interpret displacement–time and velocity–time graphs with resulting data. Where appropriate, students should use vertical error bars when plotting data. This ensures that they can determine the uncertainty of the gradient and intercepts using minimum and maximum lines of best fit.	
Newton's laws of motion • define Newton's three laws of motion and give examples of each • identify forces acting on an object • construct free-body diagrams representing forces acting on an object • determine the resultant force acting on an object in one dimension • solve problems using each of Newton's three laws of motion • define the terms *momentum* and *impulse* • recall the principle of conservation of momentum • solve problems involving momentum, impulse, the conservation of momentum and collisions in one dimension • determine and interpret the area under a force–time graph.	• **Notional time:** 6 hours • **Stimulus question:** Can physics help athletes perform better? • Students should be able to label forces such as the force due to gravity (weight), the normal force, tension, friction, drag and applied forces. • Students should be able to use free-body diagrams to calculate forces. However, they are not required to calculate drag and friction forces directly using the formulas $F_D = \frac{1}{2}\rho v^2 C_D A$ and $F_f = \mu F_N$. • In Unit 2, students are not required to determine resultant forces from constituent forces acting in more than one dimension. • Areas under graphs should be found using simple geometry, not calculus. • **Formulas:** $a_{net} = \frac{F_{net}}{m}$ $p = mv$ $\sum mv_{before} = \sum mv_{after}$ • **SHE:** Students could appreciate that Ptolemy, Aristotle, Copernicus, Galileo and Newton developed many complex models and theories describing motion and force. The development of these models and theories required a wide range of evidence, some of which was provided by predecessors.
Energy • define the terms *mechanical work*, *kinetic energy* and *gravitational potential energy* • solve problems involving work done by a force • solve problems involving kinetic energy and gravitational potential energy • determine and interpret the area under a force–displacement graph • interpret meaning from an energy–time graph • define the terms *elastic collision* and *inelastic collision* • compare and contrast elastic and inelastic collisions	• **Notional time:** 6 hours • Areas under graphs should be found using simple geometry, not calculus. • Problems may include collisions of two objects or explosions and involve previously studied formulas. • **Suggested practical:** Conduct an experiment to investigate a linear elastic collision between two objects. • **Formulas:** $W = \Delta E$ $W = Fs$

Subject matter	Guidance
• solve problems involving elastic collisions and inelastic collisions.	$E_k = \frac{1}{2}mv^2$ $\Delta E_p = mg\Delta h$ $\sum\frac{1}{2}mv^2_{before} = \sum\frac{1}{2}mv^2_{after}$
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Road safety and technology:** Knowledge of forces and motion has led to improvements in car safety through the development and use of devices such as seatbelts, crumple zones and airbags. • **Sports science:** Biomechanics applies the laws of force and motion to gain greater understanding of athletic performance through direct measurement, computer simulations and mathematical modelling. • **Development and limitations of Newton's laws:** Newton's laws provided an explanation for a range of previously unexplained physical phenomena and were confirmed by multiple experiments performed by a multitude of scientists.

3.4 Topic 2: Waves

In this topic, students will:

Subject matter	Guidance
Wave properties • recall that waves transfer energy • define the term *mechanical wave* • compare the terms *transverse wave* and *longitudinal wave* • describe examples of transverse and longitudinal waves, such as sound, seismic waves and vibrations of stringed instruments • recall the terms *compression*, *rarefaction*, *crest*, *trough*, *displacement*, *amplitude*, *period*, *frequency*, *wavelength* and *velocity*, identifying them on graphical and visual representations of a wave • interpret and calculate the amplitude, period, frequency and wavelength from graphs of transverse and longitudinal waves • solve problems involving the wavelength, frequency, period and velocity of	• **Notional time:** 7 hours • Students should be able to use their understanding of reflection and refraction to solve problems involving the apparent position of objects that are under water and to explain the shape of the sun at sunset. • Simple waves are those whose wavefronts are moving 180° to each other, e.g. waves moving in opposite directions in a string, or sound waves in a pipe. • **Suggested practical:** Conduct an experiment to 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. • **Formulas:** $v = f\lambda$

Subject matter	Guidance
a wave • define the terms *reflection*, *refraction*, *diffraction* and *superposition* • using the wave model of light, explain phenomena related to reflection and refraction • describe the reflection and refraction of a wave at a boundary between two media • apply the principle of superposition to determine the resultant amplitude of two simple waves • explain constructive interference and destructive interference of two simple waves • explain the formation of standing waves in terms of superposition with reference to constructive and destructive interference, and nodes and antinodes.	$f = \frac{1}{T}$
Sound • solve problems involving standing wave formation in pipes open at both ends, closed at one end, and on stretched strings • define the concept of resonance in a mechanical system • define the concept of natural frequency • identify that energy is transferred efficiently in resonating systems.	• **Notional time:** 6 hours • The lowest frequency will be referred to as the fundamental (or first harmonic). All other modes are referred to as harmonics, not overtones. • **Suggested practicals:** – Conduct an experiment to investigate fundamental and harmonic wavelengths in pipes. – Conduct an experiment to calculate the speed of sound in air at a specific temperature. • **Formulas:** $L = n\frac{\lambda}{2}$ $L = (2n-1)\frac{\lambda}{4}$
Light • recall that light is not modelled as a mechanical wave, because it can travel through a vacuum • recall that a wave model of light can explain reflection, refraction, total internal reflection, dispersion, diffraction and interference • describe polarisation using a transverse wave model • use ray diagrams to demonstrate the reflection and refraction of light • solve problems involving the reflection of light on plane mirrors	• **Notional time:** 10 hours • Students do not need to use the lens or mirror formula to determine location. Only one lens or mirror should be used at a time. • Students should be able to construct ray diagrams to find the location, orientation and size of an image formed by a single concave lens and a single convex lens. • Students should know that intensity is proportional to the square of amplitude.

Subject matter	Guidance
• define Snell's Law • solve problems involving the refraction of light at the boundary between two mediums • recall that the speed of light in a vacuum is $c = 3 \times 10^8 m\ s^{-1}$ • contrast the speed of light and the speed of mechanical waves • define the concept of intensity • solve problems involving the proportional relationship between intensity of light and the inverse-square of the distance from the source. • **Mandatory practical:** Conduct an experiment to determine the refractive index of a transparent substance.	• **Suggested practical:** Conduct an experiment to verify the law of reflection. • **Formulas:** $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$ $I \propto \frac{1}{r^2}$ • **SHE:** The Michelson–Morley experiment with light demonstrated the wave properties of light and that it travelled through a vacuum, disproving the luminiferous aether theory.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Monitoring earthquakes and tsunamis:** 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. • **Noise pollution and acoustic design:** Using an understanding of the behaviour of sound waves, 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. • **Development of the wave theory of light:** From the late 17th century through to the 1860s, scientists continued to refine their understanding of light and its wave-like behaviour through experimentation.

3.5 Assessment guidance

In constructing assessment instruments for Unit 2, schools should ensure that the objectives cover, or are chosen from, the unit objectives. If one assessment instrument is developed for a unit, it must assess all the unit objectives; if more than one assessment instrument is developed, the unit objectives must be covered across those instruments.

It is suggested that student performance on Unit 2 is assessed using techniques modelled on the techniques used in Unit 3:

- a student experiment
- an examination that includes some items modelled on the data test.

4 Unit 3: Gravity and electromagnetism

4.1 Unit description

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.

4.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

Unit objective	IA1	IA2	EA
1. describe and explain gravity and motion, and electromagnetism			●
2. apply understanding of gravity and motion, and electromagnetism	●	●	●
3. analyse evidence about gravity and motion, and electromagnetism	●	●	●
4. interpret evidence about gravity and motion, and electromagnetism	●	●	●
5. investigate phenomena associated with gravity and motion, and electromagnetism		●	
6. evaluate processes, claims and conclusions about gravity and motion, and electromagnetism		●	
7. communicate understandings, findings, arguments and conclusions about gravity and motion, and electromagnetism		●	

4.3 Topic 1: Gravity and motion

In this topic, students will:

Subject matter	Guidance
Vectors • use 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.	• **Notional time:** 2 hours • **Syllabus link:** Students should be able to define the term *vector* and determine the addition and subtraction of two vectors in one dimension (Unit 2 Topic 1: Linear motion and force).
Projectile motion • recall that the horizontal and vertical components of a velocity vector are independent of each other • apply vector analysis to determine horizontal and vertical components of projectile motion • solve problems involving projectile motion. • **Mandatory practical:** Conduct an experiment to determine the horizontal distance travelled by an object projected at various angles from the horizontal.	• **Notional time:** 4 hours • Students do not need to account for the effect of drag on either horizontal or vertical motion. • **Formulas:** $v_y = gt + u_y$ $s_y = \frac{1}{2}gt^2 + u_y t$ $v_y^2 = 2gs_y + u_y^2$ $v_x = u_x$ $s_x = u_x t$ • **Syllabus link:** Students should be able to recall that the acceleration due to gravity is constant near the Earth's surface and solve problems involving the equations of uniformly accelerated motion in one dimension (Unit 2 Topic 1: Linear motion and force).
Inclined planes • solve problems involving force due to gravity (weight) and mass using the mathematical relationship between them • define the term *normal force* • describe and represent the forces acting on an object on an inclined plane through the use of free-body diagrams • calculate the net force acting on an object on an inclined plane through vector analysis.	• **Notional time:** 4 hours • Forces acting on an object on an inclined plane include force due to gravity (weight), the normal force, tension, frictional force and applied force. Calculation of frictional force using $F_f = \mu F_N$ is not required. • **Suggested practical:** Conduct an experiment to investigate the parallel component of the weight of an object down an inclined plane at various angles. • **Formula:** $F_g = mg$ • **Syllabus link:** Students should be able to define Newton's three laws of motion

Subject matter	Guidance
	and describe examples of each (Unit 2 Topic 1: Linear motion and force).
Circular motion • describe uniform circular motion in terms of a force acting on an object in a perpendicular direction to the velocity of the object • define the concepts of average speed and period • solve problems involving average speed of objects undergoing uniform circular motion • define the terms *centripetal acceleration* and *centripetal force* • solve problems involving forces acting on objects in uniform circular motion.	• **Notional time:** 4 hours • **Stimulus question:** How can you travel at a constant speed yet be accelerating? • **Suggested practical:** Conduct an experiment to investigate the net forces acting on an object undergoing horizontal circular motion on a string. • **Formulas:** $v = \frac{2\pi r}{T}$ $a_c = \frac{v^2}{r}$ $F_{net} = \frac{mv^2}{r}$
Gravitational force and fields • recall Newton's Law of Universal Gravitation • solve problems involving the magnitude of the gravitational force between two masses • define the term *gravitational fields* • solve problems involving the gravitational field strength at a distance from an object.	• **Notional time:** 4 hours • **Suggested practical**: Conduct an experiment (using simulations) to investigate the gravitational force between two objects by varying the mass and distance. • **Formulas:** $F = \frac{GMm}{r^2}$ $g = \frac{F}{m} = \frac{GM}{r^2}$ • **SHE:** Students could explore the international collaboration required in the discovery of gravity waves and associated technologies, e.g. Laser Interferometer Gravitational Wave Observatory (LIGO). • **Syllabus link:** Students should be able to consider how gravity keeps planets in orbit around the sun (Unit 2 Topic 1: Linear motion and force).
Orbits • recall Kepler's laws of planetary motion • solve problems involving Kepler's third law • recall that Kepler's third law can be derived from the relationship between Newton's Law of Universal Gravitation and uniform circular motion.	• **Notional time:** 4 hours • **Stimulus question:** What is the difference between the heliocentric and geocentric models of the solar system? • **Suggested practical:** Conduct an experiment to investigate the relationship between orbital radius and mass for orbiting objects (simulation). • **Formula:** $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$

Subject matter	Guidance
	• **SHE:** Students could – 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. • **Syllabus link:** Students should be able to recall the Law of Conservation of Energy (Unit 1 Topic 1: Heating processes).
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Forensic science:** Forensic evidence is often used in court. However, despite messages in the popular media, forensic science cannot always provide sufficient conclusive evidence to lead to convictions. • **Artificial satellites:** Knowledge of orbital heights and speeds allows satellites to be best positioned for observation of weather, natural phenomena, traffic and military movements. • **Developing understanding of planetary motion:** From Ptolemy to Newton, the accepted model of the solar system slowly shifted under the influence of carefully collected and analysed data.

4.4 Topic 2: Electromagnetism

In this topic, students will:

Subject matter	Guidance
Electrostatics • define Coulomb's Law and recognise that it describes the force exerted by electrostatically charged objects on other electrostatically charged objects • solve problems involving Coulomb's Law • define the terms *electric fields*, *electric field strength* and *electrical potential energy* • solve problems involving electric field strength • solve problems involving the work done when an electric charge is moved in an	• **Notional time:** 7 hours • **Suggested practical**: Conduct an experiment to investigate the effects of electrostatic charge on various materials, e.g. on trickling water, Coulomb meter. • **Formulas:** $F = \frac{1}{4\pi\varepsilon_o}\frac{Qq}{r^2}$ $\frac{1}{4\pi\varepsilon_o} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$

Subject matter	Guidance
electric field.	$E = \frac{F}{Q} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$ $V = \frac{\Delta U}{q}$ • **Syllabus links** – Students should be able to recall that electric charge can be positive or negative, define electrical potential difference, and solve problems involving electric potential (Unit 1 Topic 3: Electrical circuits). – Students should be able to describe examples of each of Newton's three laws of motion (Unit 2 Topic 1: Linear motion and force). – Students should be able to determine the addition and subtraction of vectors in two dimensions (Unit 3 Topic 1: Gravity and motion).
Magnetic fields • define the term *magnetic field* • recall how to represent magnetic field lines, including sketching magnetic field lines due to a moving electric charge, electric currents and magnets • recall that a moving electric charge generates a magnetic field • determine the magnitude and direction of a magnetic field around electric current-carrying wires and inside solenoids • solve problems involving the magnitude and direction of magnetic fields around a straight electric current-carrying wire and inside a solenoid • recall that electric current-carrying conductors and moving electric charges experience a force 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. • **Mandatory practicals** – Conduct an experiment to investigate the force acting on a conductor in a magnetic field. – Conduct an experiment to investigate the strength of a magnet at various distances.	• **Notional time:** 7 hours • **Formulas:** $B = \frac{\mu_o I}{2\pi r}$ $\mu_o = 4\pi \times 10^{-7}\ T\ A^{-1}\ m$ $B = \mu_o nI$ $F = BILsin\theta$ $F = qvBsin\theta$ • **Syllabus links** – Students should be able to recall that electric charge is conserved at all points in an electrical circuit (Unit 1 Topic 3: Electrical circuits). – Students should be able to describe examples of each of Newton's three laws of motion (Unit 2 Topic 1: Linear motion and force). – Students should be able to determine the addition and subtraction of vectors in two dimensions (Unit 3 Topic 1: Gravity and motion).

Subject matter	Guidance
Electromagnetic induction • define the terms *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 • describe the process of inducing an EMF across a moving conductor in a magnetic field • solve problems involving Faraday's Law and Lenz's Law • 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.	• **Notional time**: 7 hours • **Stimulus question:** How is electricity made? • **Suggested practicals** – Conduct an experiment to investigate the induction of an electric current using a magnet and coil. – Conduct an experiment to investigate the induced EMF from an AC generator. • **Formulas:** $\emptyset = BAcos\theta$ $emf = -\frac{n\Delta(BA_{\perp})}{\Delta t}$ $emf = -n\frac{\Delta\phi}{\Delta t}$ $I_pV_p = I_sV_s$ $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ • **Syllabus links** – Students should be able to recall the Law of Conservation of Energy (Unit 1 Topic 1: Heating processes). – Students should be able to recall that electric charge is conserved at all points in an electrical circuit (Unit 1 Topic 3: Electrical circuits). – Students should be able to determine the addition and subtraction of vectors in two dimensions (Unit 3 Topic 1: Gravity and motion). • **SHE:** Students could explore – how scientific knowledge has been used to develop methods of renewable energy production (e.g. wind and wave power generation) – scientific evidence about the risks of electromagnetic phenomena and associated technologies (e.g. wi-fi and mobile phones) as reported in the media – the international collaboration involved in the development of the Square Kilometre Array (SKA) and the associated technologies.

Subject matter	Guidance
Electromagnetic radiation • define and explain electromagnetic radiation in terms of electric fields and magnetic fields.	• **Notional time:** 2 hours • **Syllabus links** − Students should be able to recall the properties of gamma radiation (Unit 1 Topic 2: Ionising radiation and nuclear reactions). − Students should be able to recall the properties of waves (Unit 2 Topic 2: Waves).
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for a research investigation.	• **Medical imaging:** Due to the strong magnetic fields used in MRI machines, many safety procedures must be followed, such as excluding patients with some metallic implants from receiving MRI scans. • **The Square Kilometre Array:** The Square Kilometre Array (SKA), a joint scientific project between Australia, New Zealand and South Africa, aims to gather information to advance our knowledge of dark matter, dark energy, cosmic magnetism and general relativity. • **Superconductivity:** A series of discoveries caused a number of theories to be put forward to explain superconductivity, but it was not until the late 1950s that a complete atomic scale theory of superconductivity was proposed.

4.5 Assessment

4.5.1 Summative internal assessment 1 (IA1): Data test (10%)

Description

This assessment focuses on the application of a range of cognitions to multiple provided items.

Student responses must be completed individually, under supervised conditions, and in a set timeframe.

Assessment objectives

This assessment technique is used to determine student achievement in the following 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 evidence 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.

Note: Objectives 1, 5, 6 and 7 are not assessed in this instrument.

Specifications

Description

Students respond to items using qualitative data and/or quantitative data derived from the mandatory or suggested practicals, activities or case studies from the unit being studied.

The data test contains two to four datasets and consists of a number of different types of items, which include:

- short response items requiring single-word, sentence or short paragraph responses
- calculating using algorithms
- interpreting datasets.

Mark allocations

Percentage of marks	Objective	Cognition and nature of response
~ 30%	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	Students calculate, identify, recognise and use evidence to determine unknown scientific quantities or features.
~ 30%	3. analyse evidence about gravity and motion, or electromagnetism to identify trends, patterns, relationships, limitations or uncertainty in datasets	Students categorise, classify, contrast, distinguish, organise or sequence evidence to identify trends, patterns, relationships, limitations or uncertainty in datasets.
~ 40%	4. interpret evidence about gravity and motion, or electromagnetism to draw conclusions based on analysis of datasets	Students compare, deduce extrapolate, infer, justify or predict using evidence to draw conclusions based on analysis of the datasets.

Conditions

- Time: 60 minutes plus 10 minutes perusal.
- Length: up to 500 words in total, consisting of
  - short responses, i.e. single words, sentences or short paragraphs (fewer than 50 words)
  - paragraphs, 50–250 words per item
  - other types of item responses (e.g. interpreting and calculating) should allow students to complete the response in the set time.
- Other:
  - QCAA-approved graphics calculator permitted
  - Physics formula and data booklet permitted
  - unseen stimulus.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment objectives and mark allocation for the data test.

Criterion	Objectives	Marks
Data test	2, 3, 4	10
Total		**10**

Note: Unit objectives 1, 5, 6 and 7 are not assessed in this instrument.

Instrument-specific marking guide

Criterion: Data test

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 evidence 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

The student work has the following characteristics:	Cut-off	Mark
• consistent demonstration, across a range of scenarios about gravity and motion, or electromagnetism, of – selection and correct application of scientific concepts, theories, models and systems to predict outcome/s, 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, in scenarios about gravity and motion, or electromagnetism, of – selection and correct application of scientific concepts, theories, models and systems to predict outcome/s, 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, in scenarios about gravity and motion, or electromagnetism, of – selection and correct application of scientific concepts, theories, models and systems to predict outcome/s, 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, in scenarios about gravity and motion, or electromagnetism, of elements of – selection and correct application of scientific concepts, theories, models and systems to predict outcome/s, 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

<table>
<tr><th>The student work has the following characteristics:</th><th>Cut-off</th><th>Mark</th></tr>
<tr><td rowspan="2">• demonstration, in scenarios about gravity and motion, or electromagnetism, of elements of
– application of scientific concepts, theories, models or systems to predict outcome/s, 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.</td><td>> 10%</td><td>2</td></tr>
<tr><td>> 1%</td><td>1</td></tr>
<tr><td>• does not satisfy any of the descriptors above.</td><td>≤ 1%</td><td>0</td></tr>
</table>

4.5.2 Summative internal assessment 2 (IA2): Student experiment (20%)

Description

This assessment requires students to research a question or hypothesis through collection, analysis and synthesis of primary data. A student experiment uses investigative practices to assess a range of cognitions in a particular context. Investigative practices include locating and using information beyond students' own knowledge and the data they have been given.

Research conventions must be adhered to. This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

2. apply understanding of gravity and motion, or electromagnetism to modify experimental methodologies and process primary data
3. analyse experimental evidence about gravity and motion, or electromagnetism
4. interpret experimental evidence about gravity and motion, or electromagnetism
5. investigate phenomena associated with gravity and motion, or electromagnetism, through an experiment
6. evaluate experimental processes and conclusions about gravity and motion, or electromagnetism
7. communicate understandings and experimental findings, arguments and conclusions about gravity and motion, or electromagnetism.

Note: Objective 1 is not assessed in this instrument.

Specifications

Description

In the student experiment, students modify (i.e. refine, extend or redirect) an experiment in order to address their own related hypothesis or question. It is sufficient that students use a practical performed in class or a simulation as the basis for their methodology and research question.

In order to complete the assessment task, students must:

- 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 sufficient and 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 extensions to the experiment
- communicate findings in an appropriate scientific genre (e.g. report, poster presentation, journal article, conference presentation).

*The steps indicated with an asterisk above may be completed in groups. All other elements must be completed individually.

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.

Conditions

- Time: 10 hours class time. This time will not necessarily be sequential. Students must perform the majority of the task during class time, including
  - performing background research and developing the methodology
  - conducting the experiment
  - processing and analysing evidence and evaluating the methodology
  - preparing and presenting the response (e.g. writing the scientific report, constructing and presenting the scientific poster).
- Length:
  - written (e.g. scientific report), 1500–2000 words

    or
  - multimodal presentation (e.g. scientific poster presentation), 9–11 minutes.
- Other:
  - students may work collaboratively with other students to develop the methodology and perform the experiment; all other stages (e.g. processing of data, analysis of evidence and evaluation of the experimental process) must be carried out individually
  - the response must be presented using an appropriate scientific genre (e.g. report, poster presentation, journal article, conference presentation) and contain
    - a research question
    - a rationale for the experiment
    - reference to the initial experiment and identification and justification of modifications to the methodology
    - raw and processed qualitative data and/or quantitative data
    - analysis of the evidence
    - conclusion/s based on the interpretation of the evidence
    - evaluation of the methodology and suggestions of improvements and extensions to the experiment
    - a reference list.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment objectives and mark allocation for the student experiment.

Criterion	Objectives	Marks
Research and planning	2, 5	6
Analysis of evidence	2, 3, 5	6
Interpretation and evaluation	4, 6	6
Communication	7	2
Total		**20**

Note: Unit objective 1 is not assessed in this instrument.

Instrument-specific marking guide

Criterion: Research and planning

Assessment objectives

2. apply understanding of gravity and motion, or electromagnetism to modify experimental methodologies and process primary data
5. investigate phenomena associated with gravity and motion, or electromagnetism through an experiment

The student work has the following characteristics:	Marks
• informed application of understanding of gravity and motion, or electromagnetism to modify experimental methodologies demonstrated by – a considered rationale for the experiment – justified modifications to the methodology • effective and efficient investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by – a specific and relevant research question – a methodology that enables the collection of sufficient, relevant data – considered management of risks and ethical or environmental issues.	5–6
• adequate application of understanding of gravity and motion, or electromagnetism to modify experimental methodologies demonstrated by – a reasonable rationale for the experiment – feasible modifications to the methodology • effective investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by – a relevant research question – a methodology that enables the collection of relevant data – management of risks and ethical or environmental issues.	3–4

The student work has the following characteristics:	Marks
• rudimentary application of understanding of gravity and motion, or electromagnetism to modify experimental methodologies demonstrated by – a vague or irrelevant rationale for the experiment – inappropriate modifications to the methodology • ineffective investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by – an inappropriate research question – a methodology that causes the collection of insufficient and irrelevant data – inadequate management of risks and ethical or environmental issues.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis of evidence

Assessment objectives

2. apply understanding of gravity and motion, or electromagnetism to modify experimental methodologies and process primary data
3. analyse experimental evidence about gravity and motion, or electromagnetism
5. investigate phenomena associated with gravity and motion, or electromagnetism through an experiment

The student work has the following characteristics:	Marks
• appropriate application of algorithms, visual and graphical representations of data about gravity and motion, or electromagnetism demonstrated by correct and relevant processing of data • systematic and effective analysis of experimental evidence about gravity and motion, or electromagnetism, demonstrated by – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of the uncertainty and limitations of evidence • effective and efficient investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by the collection of sufficient and relevant raw data.	5–6
• adequate application of algorithms, visual and graphical representations of data about gravity and motion, or electromagnetism demonstrated by basic processing of data • effective analysis of experimental evidence about gravity and motion or electromagnetism, demonstrated by – identification of obvious trends, patterns or relationships – basic identification of uncertainty and limitations of evidence • effective investigation of phenomena associated with gravity and motion or electromagnetism, demonstrated by the collection of relevant raw data.	3–4
• rudimentary application of algorithms, visual and graphical representations of gravity and motion, or electromagnetism demonstrated by incorrect or irrelevant processing of data • ineffective analysis of experimental evidence about gravity and motion, or electromagnetism demonstrated by – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of uncertainty and limitations of evidence • ineffective investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by the collection of insufficient and irrelevant raw data.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Interpretation and evaluation

Assessment objectives

4. interpret experimental evidence about gravity and motion, or electromagnetism
6. evaluate experimental processes and conclusions about gravity and motion, or electromagnetism

The student work has the following characteristics:	Marks
• insightful interpretation of experimental evidence about gravity and motion, or electromagnetism demonstrated by justified conclusion/s linked to the research question • critical evaluation of experimental processes about gravity and motion, or electromagnetism demonstrated by – 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.	5–6
• adequate interpretation of experimental evidence about gravity and motion, or electromagnetism demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of experimental processes about gravity and motion, or electromagnetism demonstrated by – reasonable description of the reliability and validity of the experimental process – suggested improvements and extensions to the experiment that are related to the analysis of evidence.	3–4
• invalid interpretation of experimental evidence about gravity and motion, or electromagnetism demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of experimental processes about gravity and motion, or electromagnetism demonstrated by – cursory or simplistic statements about the reliability and validity of the experimental process – ineffective or irrelevant suggestions.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objective

7. communicate understandings and experimental findings, arguments and conclusions about gravity and motion, or electromagnetism

The student work has the following characteristics:	Marks
• effective communication of understandings and experimental findings, arguments and conclusions about gravity and motion, or electromagnetism demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and experimental findings, arguments and conclusions about gravity and motion, or electromagnetism demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

4.5.3 Summative external assessment (EA): Examination (50%)

General information

Summative external assessment is developed and marked by the QCAA. In Physics, it contributes 50% to a student's overall subject result.

Summative external assessment assesses learning from both Units 3 and 4.

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

See Section 5.6.2 for more information.

5 Unit 4: Revolutions in modern physics

5.1 Unit description

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.

5.2 Unit objectives

Unit objectives are drawn from the syllabus objectives and are contextualised for the subject matter and requirements of the unit. Each unit objective must be assessed at least once.

Students will:

Unit objective	IA3	EA
1. describe and explain special relativity, quantum theory and the Standard Model		●
2. apply understanding of special relativity, quantum theory and the Standard Model	●	●
3. analyse evidence about special relativity, quantum theory and the Standard Model	●	●
4. interpret evidence about special relativity, quantum theory and the Standard Model	●	●
5. investigate phenomena associated with special relativity, quantum theory and the Standard Model	●	
6. evaluate processes, claims and conclusions about special relativity, quantum theory and the Standard Model	●	
7. communicate understandings, findings, arguments and conclusions about special relativity, quantum theory and the Standard Model.	●	

5.3 Topic 1: Special relativity

In this topic, students will:

Subject matter	Guidance
Special relativity • describe an example of natural phenomena that cannot be explained by Newtonian physics, such as the presence of muons in the atmosphere • define the terms *frame of reference* and *inertial frame of reference* • recall the two postulates of special relativity • recall that motion can only be measured relative to an observer • explain the concept of simultaneity • recall the consequences of the constant speed of light in a vacuum, e.g. time dilation and length contraction • define the terms *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 • solve problems involving time dilations, length contraction and relativistic momentum • recall the mass–energy equivalence relationship • explain why no object can travel at the speed of light in a vacuum • explain paradoxical scenarios such as the twins' paradox, flashlights on a train and the ladder in the barn paradox.	• **Notional time:** 16 hours • **Formulas:** $t = \frac{t_o}{\sqrt{(1-\frac{v^2}{c^2})}}$ $L = L_o\sqrt{(1-\frac{v^2}{c^2})}$ $p_v = \frac{m_o v}{\sqrt{(1-\frac{v^2}{c^2})}}$ $\Delta E = \Delta mc^2$ • **Syllabus links** − Students should be able to define momentum and impulse, solve problems on momentum and impulse, recall Newton's laws of motion, and solve problems using Newton's laws of motion (Unit 2 Topic 1: Linear motion and force). − Students should be able to recall the speed of light (Unit 2 Topic 2: Waves). • **SHE:** Students could explore how technologies such as satellites have dramatically increased the size, accuracy, and geographic and temporal scope of datasets with which scientists work. They should also be aware that satellites provide experimental evidence that supports the phenomena of time dilation.

Subject matter	Guidance
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for the research investigation.	• **Development of the special theory of relativity:** Albert Einstein's work on special relativity built upon the work of scientists such as Maxwell and Lorentz, while subsequent studies by Max Planck, Hermann Minkowski and others led to the development of relativistic theories of gravitation, mass–energy equivalence and quantum field theory. • **Ring laser gyroscopes and navigation:** Ring laser gyroscopes (RLG) are inertial guidance systems that do not rely on signals from an external source, but from instruments on board a moving object and are used in helicopters, ships, submarines and missiles for accurate navigation. • **Nuclear reactors:** Special relativity leads to the idea of mass–energy equivalence, which has been applied in nuclear fission reactors.

5.4 Topic 2: Quantum theory

In this topic, students will:

Subject matter	Guidance
Quantum theory • explain how Young's double slit experiment provides evidence for the wave model of light • describe light as an electromagnetic wave produced by an oscillating electric charge that produces mutually perpendicular oscillating electric fields and magnetic fields • explain the concept of black-body radiation • identify that black-body radiation provides evidence that electromagnetic radiation is quantised into discrete values • describe the concept of a photon • solve problems involving the energy, frequency and wavelength of a photon • describe the photoelectric effect in terms of the photon • define the terms *threshold frequency*, *Planck's constant* and *work function* • solve problems involving the photoelectric effect	• **Notional time:** 16 hours • Only a qualitative description of Young's double slit experiment and its outcomes needs to be developed to provide an explanation of the wave-like nature of light. • **Formulas:** $\lambda_{max} = \frac{b}{T}$ $E = hf$ $h = 6.626 \times 10^{-34}\ J\ s$ $E_k = hf - W$ $\lambda = \frac{h}{p}$ $n\lambda = 2\pi r$ $mvr = \frac{nh}{2\pi}$

Subject matter	Guidance
• recall that photons exhibit the characteristics of both waves and particles • describe Rutherford’s model of the atom including its limitations • describe the Bohr model of the atom and how it addresses the limitations of Rutherford’s model • explain how the Bohr 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 • 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. • **Mandatory practical:** Conduct an experiment (or use a simulation) to investigate the photoelectric effect. Data such as the photoelectron energy or velocity, or electrical potential difference across the anode and cathode, can be compared with the wavelength or frequency of incident light. Calculation of work functions and Planck’s constant using the data would also be appropriate.	$\frac{1}{\lambda} = R(\frac{1}{n_f^2} - \frac{1}{n_i^2})$ • **Syllabus links** – Students should be able to describe the structure of atoms and recall Einstein’s mass–energy equivalence relationship (Unit 1 Topic 2: Ionising radiation and nuclear reactions). – Students should be able to recall that waves transfer energy, recall that light cannot be modelled as a mechanical wave because it can travel through a vacuum, recall that a wave model of light can explain interference and define the concept of resonance in a mechanical system (Unit 2 Topic 2: Waves). • **SHE:** Students could explore – the historical development of the model of the atom in terms of traditional models (Democritus, Dalton, Brownian motion, Thomson, Rutherford and Bohr, etc.) – how theories are contested, refined or replaced when new evidence challenges them, or when a new model or theory has greater explanatory power – how the approximation of Earth as a black body can be used to predict climate patterns; however, many scientists face real problems in validating their models.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for the research investigation.	• **Development of the quantum model:** A more elaborate quantum mechanical model of the atom, developed from work by Rutherford, Bohr, Planck and Einstein, is required to explain many observations made about atoms. • **Black-body radiation and the greenhouse effect:** Models of Earth’s energy balance using the concept of black-body radiation enable scientists to monitor changes in global temperature, assess the evidence for changes in climate due to the enhanced greenhouse effect and evaluate the risk posed by anthropogenic climate change.

5.5 Topic 3: The Standard Model

In this topic, students will:

Subject matter	Guidance
The Standard Model • define the concept of an elementary particle and antiparticle • recall the six types of quarks • define the terms *baryon* and *meson* • recall the six types of leptons • recall the four gauge bosons • describe the strong nuclear, weak nuclear and electromagnetic forces in terms of the gauge bosons • contrast the fundamental forces experienced by quarks and leptons.	• **Notional time:** 5 hours • **Syllabus links** − Students should be able to describe and use the law of conservation of energy (Unit 1 Topic 1: Heating processes). − Students should be able to recall, describe and explain the properties of the nuclear model of the atom and strong nuclear forces (Unit 1 Topic 2: Ionising radiation and nuclear reactions). − Students should be able to recall, describe and explain the properties of electromagnetic forces (Unit 3 Topic 2: Electromagnetism).
Particle interactions • define the concept of lepton number and baryon number • recall the conservation of lepton number and baryon number in particle interaction • explain the following interactions of particles using Feynman diagrams − electron and electron − electron and positron − a neutron decaying into a proton • describe the significance of symmetry in particle interactions.	• **Notional time:** 8 hours • Students do not need to determine lepton and baryon number quantitatively. • Students should know that baryon number is conserved in all reactions. No calculations are required to show this. • Refer to supporting resources for instructions on how to represent particle interactions using Feynman diagrams. • **SHE:** Students could explore the history of particle physics models and theories through the development of particle accelerators and contributions from notable physicists.
Science as a Human Endeavour (SHE) • SHE subject matter will not be assessed on the external examination, but could be used in the development of claims and research questions for the research investigation.	• **Evidence for the Higgs boson particle:** The Large Hadron Collider was built to test particle physics theories and specifically to try to produce and detect the Higgs boson particle. • **Particle accelerators:** The construction of the Australian Synchrotron (a particle accelerator) involved collaboration between Australian and New Zealand science organisations, state and federal governments, and international organisations and committees, including the International Science Advisory Committee and the International Machine Advisory Committee.

Subject matter	Guidance
	• **The Big Bang theory:** There is a variety of evidence that supports the Big Bang theory, including cosmic background radiation, the abundance of light elements, and the red shift of light from galaxies that obey Hubble's Law.

5.6 Assessment

5.6.1 Summative internal assessment 3 (IA3): Research investigation (20%)

Description

This assessment requires students to evaluate a claim. They will do this by researching, analysing and interpreting secondary evidence from scientific texts to form the basis for a justified conclusion about the claim. A research investigation uses research practices to assess a range of cognitions in a particular context. Research practices include locating and using information beyond students' own knowledge and the data they have been given.

Research conventions must be adhered to. This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

2. apply understanding of special relativity, quantum theory or the Standard Model to develop research questions
3. analyse research evidence about special relativity, quantum theory or the Standard Model
4. interpret research evidence about special relativity, quantum theory or the Standard Model
5. investigate phenomena associated with special relativity, quantum theory or the Standard Model through research
6. evaluate research processes, claims and conclusions about special relativity, quantum theory or the Standard Model
7. communicate understandings and research findings, arguments and conclusions about special relativity, quantum theory or the Standard Model.

Note: Objective 1 is not assessed in this instrument.

Specifications

Description

In the research investigation, students gather secondary evidence related to a research question in order to evaluate the claim. The students develop their research question based on a number of possible claims provided by their teacher. Students work individually throughout this task.

Evidence must be obtained by researching scientifically credible sources, such as scientific journals, books by well-credentialed scientists and websites of governments, universities, independent research bodies or science and technology manufacturers.

In order to complete the assessment task, students must:

- select a claim to be evaluated
- identify the relevant scientific concepts associated with the claim
- pose a research question addressing an aspect of the claim
- conduct research to gather scientific evidence that may be used to address the research question and subsequently evaluate the claim

- analyse the data to identify sufficient and relevant evidence
- identify the trends, patterns or relationships in the evidence
- analyse the evidence to identify limitations
- interpret the evidence to construct justified scientific arguments
- interpret the evidence to form a justified conclusion to the research question
- discuss the quality of the evidence
- evaluate the claim by extrapolating the findings of the research question to the claim
- suggest improvements and 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.

Conditions

- Time: 10 hours class time. This time will not necessarily be sequential. Students must perform the majority of the task during class time, including
  - performing background research
  - developing the research question
  - collection of scientific evidence
  - analysing and interpreting evidence and evaluating the claim
  - preparing and presenting the response (e.g. writing the scientific essay).
- Length:
  - written (e.g.scientific essay), 1500–2000 words

    or
  - multimodal presentation (e.g. scientific conference presentation), 9–11 minutes.
- Other:
  - students are to work individually throughout this task
  - the response must be presented using an appropriate scientific genre (e.g. report, journal article, essay, conference presentation) and contain
    - a claim
    - a research question
    - a rationale for the investigation
    - justified scientific arguments using evidence
    - a conclusion to the research question based on the interpretation of the evidence
    - evaluation of the claim and suggestions of improvements and extensions to the investigation
    - a reference list.

Summary of the instrument-specific marking guide

The following table summarises the criteria, assessment objectives and mark allocation for the research investigation.

Criterion	Objectives	Marks
Research and planning	2, 5	6
Analysis and interpretation	3, 4	6
Conclusion and evaluation	4, 6	6
Communication	7	2
Total		**20**

Note: Unit objective 1 is not assessed in this instrument.

Instrument-specific marking guide

Criterion: Research and planning

Assessment objectives

2. apply understanding of special relativity, quantum theory or the Standard Model to develop research questions
5. investigate phenomena associated with special relativity, quantum theory or the Standard Model through research

The student work has the following characteristics:	Marks
• informed application of understanding of special relativity, quantum theory or the Standard Model demonstrated by a considered rationale identifying clear development of the research question from the claim • effective and efficient investigation of phenomena associated with special relativity, quantum theory or the Standard Model demonstrated by – a specific and relevant research question – selection of sufficient and relevant sources.	5–6
• adequate application of understanding of special relativity, quantum theory or the Standard Model demonstrated by a reasonable rationale that links the research question and the claim • effective investigation of phenomena associated with special relativity, quantum theory or the Standard Model demonstrated by – a relevant research question – selection of relevant sources.	3–4
• rudimentary application of understanding of special relativity, quantum theory or the Standard Model demonstrated by a vague or irrelevant rationale for the investigation • ineffective investigation of phenomena associated with special relativity, quantum theory or the Standard Model demonstrated by – an inappropriate research question – selection of insufficient and irrelevant sources.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis and interpretation

Assessment objectives

3. analyse research evidence about special relativity, quantum theory or the Standard Model
4. interpret research evidence about special relativity, quantum theory or the Standard Model

The student work has the following characteristics:	Marks
• systematic and effective analysis of qualitative data and/or quantitative data within the sources about special relativity, quantum theory or the Standard Model demonstrated by – the identification of sufficient and relevant evidence – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of limitations of evidence • insightful interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by justified scientific argument/s.	5–6
• effective analysis of qualitative data and/or quantitative data within the sources about special relativity, quantum theory or the Standard Model demonstrated by – the identification of relevant evidence – identification of obvious trends, patterns or relationships – basic identification of limitations of evidence • adequate interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by reasonable scientific argument/s.	3–4
• rudimentary analysis of qualitative data and/or quantitative data within the sources about special relativity, quantum theory or the Standard Model demonstrated by – the identification of insufficient and irrelevant evidence – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of limitations of evidence • invalid interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by inappropriate or irrelevant argument/s.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Conclusion and evaluation

Assessment objectives

4. interpret research evidence about special relativity, quantum theory or the Standard Model
6. evaluate research processes, claims and conclusions about special relativity, quantum theory or the Standard Model

The student work has the following characteristics:	Marks
• insightful interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by justified conclusion/s linked to the research question • critical evaluation of the research processes, claims and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – insightful 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.	5–6

The student work has the following characteristics:	Marks
• adequate interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of the research processes, claims and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – reasonable description of the quality of evidence – application of relevant findings of the research to the claim – suggested improvements and extensions to the investigation that are relevant to the claim.	3–4
• invalid interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of the research processes, claims and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – 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.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objective

7. communicate understandings and research findings, arguments and conclusions about special relativity, quantum theory or the Standard Model

The student work has the following characteristics:	Marks
• effective communication of understandings and research findings, arguments and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and research findings, arguments and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

5.6.2 Summative external assessment (EA): Examination (50%)

General information

Summative external assessment is developed and marked by the QCAA. In Physics it contributes 50% to a student's overall subject result.

Summative external assessment assesses learning from both Units 3 and 4.

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

Description

The examination assesses the application of a range of cognitions to multiple provided items — questions, scenarios and problems.

Student responses must be completed individually, under supervised conditions and in a set timeframe.

Assessment objectives

This assessment technique is used to determine student achievement in the following objectives:

1. describe and explain 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 evidence 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.

Note: Objectives 5, 6 and 7 are not assessed in this instrument.

Specifications

Description

This examination will include two papers. Each paper consists of a number of different types of possible items.

- multiple choice
- short response items requiring single-word, sentence or paragraph responses
- calculating using algorithms
- interpreting graphs, tables or diagrams
- responding to unseen data and/or stimulus.

Conditions

Paper 1

- Time: 90 minutes plus 10 minutes perusal.
- Other:
  - QCAA-approved graphics calculator permitted
  - seen Physics formula and data booklet provided.

Paper 2

- Time: 90 minutes plus 10 minutes perusal.
- Other:
  - QCAA-approved graphics calculator permitted
  - seen Physics formula and data booklet provided.

Instrument-specific marking guide

No ISMG is provided for the external assessment.

6 Glossary

Term	Explanation
A	
absolute measurement uncertainty	an estimate of the dispersion of the measurement result; the range of values around the measurement result that is most likely to include the true value (ACARA 2015c)
absolute uncertainty of the mean	e.g. $\Delta\bar{x} = \pm\frac{(x_{max} - x_{min})}{2}$
acceleration	the rate at which an object's velocity changes (symbol, a; SI unit m/s^2) (Tipler & Mosca 2003, Giancoli 2008)
accomplished	highly trained or skilled in a particular activity; perfected in knowledge or training; expert
accuracy	the condition or quality of being true, correct or exact; freedom from error or defect; precision or exactness; correctness; in science, the extent to which a measurement result represents the quantity it purports to measure; an accurate measurement result includes an estimate of the true value and an estimate of the uncertainty
accurate	precise and exact; to the point; consistent with or exactly conforming to a truth, standard, rule, model, convention or known facts; free from error or defect; meticulous; correct in all details
acknowledgment	the recognition of the authority or recognition of something
adept	very/highly skilled or proficient at something; expert
adequate	satisfactory or acceptable in quality or quantity equal to the requirement or occasion
algebraic representation	a set of symbols linked by mathematical operations; the set of symbols summarises relationships between variables (ACARA 2015c)
alpha radiation	the composite particle consisting of two protons and two neutrons tightly bounded together, emitted from the nucleus of some radionuclides (symbol, α or ${}^{4}_{2}\mathrm{He}$) (Tipler & Mosca 2003, Giancoli 2008)
amplitude	the distance from the rest position of a wave (equilibrium position) to the crest position, which is half the vertical distance from a trough to a crest (Tipler & Mosca 2003, Giancoli 2008)
analyse	dissect to ascertain and examine constituent parts and/or their relationships; break down or examine in order to identify the essential elements, features, components or structure; determine the logic and reasonableness of information; examine or consider something in order to explain and interpret it, for the purpose of finding meaning or relationships and identifying patterns, similarities and differences

Term	Explanation
analysis	examination of evidence to identify the essential features, components, elements or structure; identification of patterns, similarities and differences
analytical technique	a procedure or method for analysing data
anomaly	something that deviates from what is standard, normal or expected (Taylor 1982)
antinode	the midway point between each pair of nodes where there is maximum amplitude of vibration (Tipler & Mosca 2003)
antiparticle	a particle with the same mass and opposite charge and/or spin to a corresponding particle, for example positron and electron (Tipler & Mosca 2003, Giancoli 2008)
applied learning	the acquisition and application of knowledge, understanding and skills in real-world or lifelike contexts that may encompass workplace, industry and community situations; it emphasises learning through doing and includes both theory and the application of theory, connecting subject knowledge and understanding with the development of practical skills
Applied subject	a subject whose primary pathway is work and vocational education; it emphasises applied learning and community connections; a subject for which a syllabus has been developed by the QCAA with the following characteristics: results from courses developed from Applied syllabuses contribute to the QCE; results may contribute to ATAR calculations
apply	use knowledge and understanding in response to a given situation or circumstance; carry out or use a procedure in a given or particular situation
appraise	evaluate the worth, significance or status of something; judge or consider a text or piece of work
appreciate	recognise or make a judgment about the value or worth of something; understand fully; grasp the full implications of
appropriate	acceptable; suitable or fitting for a particular purpose, circumstance, context, etc.
apt	suitable to the purpose or occasion; fitting, appropriate
area of study	a division of, or a section within a unit
argue	give reasons for or against something; challenge or debate an issue or idea; persuade, prove or try to prove by giving reasons
argument	process of reasoning; series of reasons; a statement or fact tending to support a point
artificial transmutation	the process in which an isotope is intentionally caused to change by nuclear processes into an isotope of another element (distinct from natural radioactivity) (e.g. neutron bombardment of U_{235}) (Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
aspect	a particular part of a feature of something; a facet, phase or part of a whole
assess	measure, determine, evaluate, estimate or make a judgment about the value, quality, outcomes, results, size, significance, nature or extent of something
assessment	purposeful and systematic collection of information about students' achievements
assessment instrument	a tool or device used to gather information about student achievement
assessment objectives	drawn from the unit objectives and contextualised for the requirements of the assessment instrument (see also 'syllabus objectives', 'unit objectives')
assessment technique	the method used to gather evidence about student achievement (e.g. examination, project, investigation)
astute	showing an ability to accurately assess situations or people; of keen discernment
ATAR	Australian Tertiary Admission Rank
atomic number	the number of protons in an element's nucleus, Z; in a neutral atom, the number of protons will be equal to the number of electrons orbiting the nucleus (Tipler & Mosca 2003, Giancoli 2008)
authoritative	able to be trusted as being accurate or true; reliable; commanding and self-confident; likely to be respected and obeyed
average speed	the rate of change of distance calculated by the formula $\text{average speed} = \frac{\text{distance}}{\text{time}}$ (Tipler & Mosca 2003, Giancoli 2008)
B	
balanced	keeping or showing a balance; not biased; fairly judged or presented; taking everything into account in a fair, well-judged way
baryon number	a strictly conserved additive quantum number of a system defined by $B = \frac{1}{3}(n_q - n_{\bar{q}})$, where n_q is the number of quarks and $n_{\bar{q}}$ is the number of antiquarks (Tipler & Mosca 2003, Giancoli 2008)
baryons	composite subatomic particles made up of three quarks (Tipler & Mosca 2003, Giancoli 2008)
basic	fundamental
behaviour	in science, the action of any material; the action or activity of an individual
beta negative radiation	a type of radioactive decay in which an energetic electron $({}_{-1}^{0}e)$ and associated antineutrino $({}_{0}^{0}\bar{\nu})$ are emitted from an atomic nucleus (symbol β^{-}) (Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
beta positive radiation	a type of radioactive decay in which an energetic positron (${}^{0}_{1}e$) and associated neutrino (${}^{0}_{0}\nu$) are emitted from an atomic nucleus (symbol β^+) (Tipler & Mosca 2003, Giancoli 2008)
binding energy	the mechanical work that must be done against the forces holding a nucleus together to disassemble it into component parts (Tipler & Mosca 2003, Giancoli 2008)
binding energy per nucleon	the binding energy divided by the number of nucleons in the nucleus of an atom (Tipler & Mosca 2003; Giancoli 2008)
black-body radiation	the radiation emitted by a black body from the conversion of thermal energy; a black body is a perfect absorber or emitter of radiation (Tipler & Mosca 2003; Giancoli 2008)
C	
calculate	determine or find (e.g. a number, answer) by using mathematical processes; obtain a numerical answer showing the relevant stages in the working; ascertain/determine from given facts, figures or information
categorise	place in or assign to a particular class or group; arrange or order by classes or categories; classify, sort out, sort, separate
centripetal acceleration	the acceleration experienced by any object moving in a circular path directed towards the centre of motion (symbol, a_c; SI unit is m/s^2) (Tipler & Mosca 2003; Giancoli 2008)
centripetal force	the force acting on an object travelling in a circle that constantly either pulls or pushes the object in towards the centre of motion (symbol, F_{net}; SI unit is N) (Tipler & Mosca 2003; Giancoli 2008)
challenging	difficult but interesting; testing one's abilities; demanding and thought-provoking; usually involving unfamiliar or less familiar elements
change in velocity	found by vector subtraction of the initial velocity from the final velocity (Tipler & Mosca 2003, Giancoli 2008)
characteristic	a typical feature or quality
claim	an assertion made without any accompanying evidence to support it
clarify	make clear or intelligible; explain; make a statement or situation less confused and more comprehensible
clarity	clearness of thought or expression; the quality of being coherent and intelligible; free from obscurity of sense; without ambiguity; explicit; easy to perceive, understand or interpret
classify	arrange, distribute or order in classes or categories according to shared qualities or characteristics
clear	free from confusion, uncertainty, or doubt; easily seen, heard or understood
clearly	in a clear manner; plainly and openly, without ambiguity

Term	Explanation
coherent	having a natural or due agreement of parts; connected; consistent; logical, orderly; well-structured and makes sense; rational, with parts that are harmonious; having an internally consistent relation of parts
cohesive	characterised by being united, bound together or having integrated meaning; forming a united whole
collate	to put together; to compare
collection	in science, a systematic approach to gathering and measuring evidence from a variety of sources in order to evaluate outcomes and make predictions
comment	express an opinion, observation or reaction in speech or writing; give a judgment based on a given statement or result of a calculation
communicate	convey knowledge and/or understandings to others; make known; transmit
compare	display recognition of similarities and differences and recognise the significance of these similarities and differences
competent	having suitable or sufficient skills, knowledge, experience, etc. for some purpose; adequate but not exceptional; capable; suitable or sufficient for the purpose; having the necessary ability, knowledge or skill to do something successfully; efficient and capable (of a person); acceptable and satisfactory, though not outstanding
competently	in an efficient and capable way; in an acceptable and satisfactory, though not outstanding, way
complex	composed or consisting of many different and interconnected parts or factors; compound; composite; characterised by an involved combination of parts; complicated; intricate; a complex whole or system; a complicated assembly of particulars
comprehend	understand the meaning or nature of; grasp mentally
comprehensive	inclusive; of large content or scope; including or dealing with all or nearly all elements or aspects of something; wide-ranging; detailed and thorough, including all that is relevant
compression	a region in a longitudinal wave where the particles are closest together (Tipler & Mosca 2003; Giancoli 2008)
concept	scientific concepts are an idea or model explaining some natural phenomenon; an theoretical construct; a thought, idea or notion
concise	expressing much in few words; giving a lot of information clearly and in a few words; brief, comprehensive and to the point; succinct, clear, without repetition of information
concisely	in a way that is brief but comprehensive; expressing much in few words; clearly and succinctly
conclusion	a judgment based on evidence (ACARA 2015c)

Term	Explanation
conduct	direct in action or course; manage; organise; carry out
conduction	the process by which heat or electricity is directly transferred or transmitted through the material of a substance when there is a difference of temperature or of electrical potential between adjoining regions, without movement of the material (Tipler & Mosca 2003, Giancoli 2008)
consider	think deliberately or carefully about something, typically before making a decision; take something into account when making a judgment; view attentively or scrutinise; reflect on
considerable	fairly large or great; thought about deliberately and with a purpose
considered	formed after careful and deliberate thought
consistent	agreeing or accordant; compatible; not self-opposed or self-contradictory, constantly adhering to the same principles; acting in the same way over time, especially so as to be fair or accurate; unchanging in nature, standard, or effect over time; not containing any logical contradictions (of an argument); constant in achievement or effect over a period of time
construct	create or put together (e.g. an argument) by arranging ideas or items; display information in a diagrammatic or logical form; make; build
constructive interference	the interference of two or more waves of the same, or almost the same, frequency and in phase with each other, superposing to produce an observable pattern in intensity (Tipler & Mosca 2003)
contrast	display recognition of differences by deliberate juxtaposition of contrary elements; show how things are different or opposite; give an account of the differences between two or more items or situations, referring to both or all of them throughout
controlled	shows the exercise of restraint or direction over; held in check; restrained, managed or kept within certain bounds
convection	the movement caused within a fluid by the tendency of hotter and therefore less dense material to rise, and colder, denser material to sink under the influence of gravity, which consequently results in transfer of heat (Tipler & Mosca 2003, Giancoli 2008)
convincing	persuaded by argument or proof; leaving no margin of doubt; clear; capable of causing someone to believe that something is true or real; persuading or assuring by argument or evidence; appearing worthy of belief; credible or plausible
correct	conforming to fact or truth; accurate
Coulomb's law	a law stating that like electric charges repel and opposite electric charges attract, with a force proportional to the product of the electric charges and inversely proportional to the square of the distance between them, expressed by the formula $F = \frac{1}{4\pi\epsilon_0}\frac{Qq}{r^2}$ (Tipler & Mosca 2003, Giancoli 2008)
course	a defined amount of learning developed from a subject syllabus

Term	Explanation
create	bring something into being or existence; produce or evolve from one's own thought or imagination; reorganise or put elements together into a new pattern or structure or to form a coherent or functional whole
creative	resulting from originality of thought or expression; relating to or involving the use of the imagination or original ideas to create something; having good imagination or original ideas
credible	capable or worthy of being believed; believable; convincing
crest	the highest part or point of a wave (Tipler & Mosca 2003, Giancoli 2008)
criterion	the property or characteristic by which something is judged or appraised
critical	involving skilful judgment as to truth, merit, etc.; involving the objective analysis and evaluation of an issue in order to form a judgment; expressing or involving an analysis of the merits and faults of a work of literature, music, or art; incorporating a detailed and scholarly analysis and commentary (of a text); rationally appraising for logical consistency and merit
critique	review (e.g. a theory, practice, performance) in a detailed, analytical and critical way
cursory	hasty, and therefore not thorough or detailed; performed with little attention to detail; going rapidly over something, without noticing details; hasty; superficial
D	
data	in science, measurements of an attribute or attributes; data may be quantitative or qualitative and be from primary or secondary sources (ACARA 2015c)
dataset	qualitative data and/or quantitative data (e.g. diagram, graph, image, map, photograph, table) derived from a practical, activity or case study
decide	reach a resolution as a result of consideration; make a choice from a number of alternatives
deduce	reach a conclusion that is necessarily true, provided a given set of assumptions is true; arrive at, reach or draw a logical conclusion from reasoning and the information given
defensible	justifiable by argument; capable of being defended in argument
define	give the meaning of a word, phrase, concept or physical quantity; state meaning and identify or describe qualities
demonstrate	prove or make clear by argument, reasoning or evidence, illustrating with practical example; show by example; give a practical exhibition

Term	Explanation
derive	arrive at by reasoning; manipulate a mathematical relationship to give a new equation or relationship; in mathematics, obtain the derivative of a function
describe	give an account (written or spoken) of a situation, event, pattern or process, or of the characteristics or features of something
design	produce a plan, simulation, model or similar; plan, form or conceive in the mind; in English, select, organise and use particular elements in the process of text construction for particular purposes; these elements may be linguistic (words), visual (images), audio (sounds), gestural (body language), spatial (arrangement on the page or screen) and multimodal (a combination of more than one)
destructive interference	the interference of two or more waves of the same, or almost the same frequency and 180° out of phase with each other, superposing to produce a resultant wave with reduced amplitude (Tipler & Mosca 2003)
detailed	executed with great attention to the fine points; meticulous; including many of the parts or facts
determine	establish, conclude or ascertain after consideration, observation, investigation or calculation; decide or come to a resolution
develop	elaborate, expand or enlarge in detail; add detail and fullness to; cause to become more complex or intricate
devise	think out; plan; contrive; invent
differentiate	identify the difference/s in or between two or more things; distinguish, discriminate; recognise or ascertain what makes something distinct from similar things; in mathematics, obtain the derivative of a function
diffraction	a phenomenon in which waves either bend behind a barrier or the wavefront is broken up into many small sources (Tipler & Mosca 2003, Giancoli 2008)
discerning	discriminating; showing intellectual perception; showing good judgment; making thoughtful and astute choices; selected for value or relevance
discriminate	note, observe or recognise a difference; make or constitute a distinction in or between; differentiate; note or distinguish as different
discriminating	differentiating; distinctive; perceiving differences or distinctions with nicety; possessing discrimination; perceptive and judicious; making judgments about quality; having or showing refined taste or good judgment
discuss	examine by argument; sift the considerations for and against; debate; talk or write about a topic, including a range of arguments, factors or hypotheses; consider, taking into account different issues and ideas, points for and/or against, and supporting opinions or conclusions with evidence

Term	Explanation
disjointed	disconnected; incoherent; lacking a coherent order/sequence or connection
dispersion	observed as the splitting of white light into a rainbow, dispersion is the phenomenon in which the phase velocity of a wave depends on its frequency; this is due to the dependence of the index of refraction on the wavelength of light (Tipler & Mosca 2003, Giancoli 2008)
displacement	a vector quantity representing the location of the destination relative to the origin of motion only, irrespective of the path actually taken between the two points (symbol, s; SI unit, m) (Tipler & Mosca 2003, Giancoli 2008)
distance	the total length of the pathway taken between the origin and the destination point (symbol, d; SI unit, m) (Tipler & Mosca 2003, Giancoli 2008)
distinguish	recognise as distinct or different; note points of difference between; discriminate; discern; make clear a difference/s between two or more concepts or items
diverse	of various kinds or forms; different from each other
document	support (e.g. an assertion, claim, statement) with evidence (e.g. decisive information, written references, citations)
draw conclusions	make a judgment based on reasoning and evidence
E	
effective	successful in producing the intended, desired or expected result; meeting the assigned purpose
efficiency	the ratio of useful work performed by a machine or in a process, to total energy expended or heat taken in (Tipler & Mosca 2003, Giancoli 2008)
efficient	working in a well-organised and competent way; maximum productivity with minimal expenditure of effort; acting or producing effectively with a minimum of waste, expense or unnecessary effort
elastic collision	a collision in which both momentum and kinetic energy are conserved (Tipler & Mosca 2003, Giancoli 2008)
electric charge	a physical property of an object that causes it to experience a force when placed in an electromagnetic field (Tipler & Mosca 2003, Giancoli 2008)
electric current	the rate of movement of electric charge carriers from one part of a conductor to another (Tipler & Mosca 2003, Giancoli 2008)
electric field strength	the intensity of an electric field at a particular location (Tipler & Mosca 2003, Giancoli 2008)
electric fields	regions around an electrically charged particle or object within which a force would be exerted on other electrically charged particles or objects (Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
electrical potential difference	the change in potential energy per unit charge between two defined points in a circuit; the unit of electrical potential difference is volts V; sometimes referred to as the *voltage* (Tipler & Mosca 2003, Giancoli 2008)
electrical potential energy	the capacity of electric charge carriers to do work due to their position in an electric circuit (Tipler & Mosca 2003, Giancoli 2008)
electromagnetic force	one of the four fundamental forces; the electromagnetic force is mediated by photons (Tipler & Mosca 2003, Giancoli 2008)
electromagnetic induction	the production of an electromotive force (EMF) or voltage across an electrical conductor due to its dynamic interaction with a magnetic field (Tipler & Mosca 2003, Giancoli 2008)
electromagnetic radiation	radiant energy consisting of synchronised oscillations of electric and magnetic fields, or electromagnetic waves, propagated at the speed of light in a vacuum (Tipler & Mosca 2003, Giancoli 2008)
electromagnetic waves	produced by an oscillating electric charge resulting in mutually perpendicular electric and magnetic fields (Tipler & Mosca 2003, Giancoli 2008)
electromotive force	a difference in potential that tends to give rise to an electric current, also written as emf (Tipler & Mosca 2003, Giancoli 2008)
electron	a lepton with a negative electric charge
electron volt	a unit of energy equal to the work done on an electron in accelerating it through an electrical potential difference of 1 volt (unit, eV) (Tipler & Mosca 2003, Giancoli 2008)
electrostatic repulsion	the repulsion experienced by two like charged particles
element	a component or constituent part of a complex whole; a fundamental, essential or irreducible part of a composite entity
elementary	simple or uncompounded; relating to or dealing with elements, rudiments or first principles (of a subject); of the most basic kind; straightforward and uncomplicated
elementary particle	a particle whose substructure is unknown (Tipler & Mosca 2003, Giancoli 2008)
energy	the capacity to do mechanical work; the higher the energy content the greater the impact when it is transformed or transferred (Tipler & Mosca 2003, Giancoli 2008)
energy transfer	the movement of energy from one system to another
energy transformation	the change of energy from one form to another (such as gravitational potential energy to kinetic energy for a falling object)
environment	all the surroundings, both living and non-living
erroneous	based on or containing error; mistaken; incorrect
essential	absolutely necessary; indispensable; of critical importance for achieving something

Term	Explanation
evaluate	make an appraisal by weighing up or assessing strengths, implications and limitations; make judgments about ideas, works, solutions or methods in relation to selected criteria; examine and determine the merit, value or significance of something, based on criteria
evidence	in science, data that has been selected as it is considered reliable and valid and can be used to support a particular idea, conclusion or decision; evidence gives weight or value to data by considering its credibility, acceptance, bias, status, appropriateness and reasonableness (ACARA 2015c)
examination	a supervised test that assesses the application of a range of cognitions to one or more provided items such as questions, scenarios and/or problems; student responses are completed individually, under supervised conditions, and in a set timeframe
examine	investigate, inspect or scrutinise; inquire or search into; consider or discuss an argument or concept in a way that uncovers the assumptions and interrelationships of the issue
experiment	try out or test new ideas or methods, especially in order to discover or prove something; undertake or perform a scientific procedure to test a hypothesis, make a discovery or demonstrate a known fact in science, an investigation that involves carrying out a practical activity
experimental	relating to, derived from, or founded on experiment
explain	make an idea or situation plain or clear by describing it in more detail or revealing relevant facts; give an account; provide additional information
explicit	clearly and distinctly expressing all that is meant; unequivocal; clearly developed or formulated; leaving nothing merely implied or suggested
explore	look into both closely and broadly; scrutinise; inquire into or discuss something in detail
express	convey, show or communicate (e.g. a thought, opinion, feeling, emotion, idea or viewpoint); in words, art, music or movement, convey or suggest a representation of; depict
extend	in science, to extend an experiment is to modify the methodology to overcome limitations of the scope or applicability of the data
extended response	an open-ended assessment technique that focuses on the interpretation, analysis, examination and/or evaluation of ideas and information in response to a particular situation or stimulus; while students may undertake some research when writing the extended response, it is not the focus of this technique; an extended response occurs over an extended and defined period of time; an item on an examination may also require an extended response, either written or oral

Term	Explanation
Extension subject	a two-unit subject for which a syllabus has been developed by QCAA; it is an extension of one or more general or alternative sequence subject/s; studied concurrently with the final two units of that subject/s or after completion of, the final two units of that subject/s
extensions	in science, modifications to an investigation that could be used to further examine a claim
extensive	of great extent; wide; broad; far-reaching; comprehensive; lengthy; detailed; large in amount or scale
external assessment	summative assessment that occurs towards the end of a course of study and is common to all schools; developed and marked by the QCAA according to a commonly applied marking scheme
external examination	a supervised test, developed and marked by the QCAA, that assesses the application of a range of cognitions to multiple provided items such as questions, scenarios and/or problems; student responses are completed individually, under supervised conditions, and in a set timeframe
extrapolate	infer or estimate by extending or projecting known information; conjecture; infer from what is known; extend the application of something (e.g. a method or conclusion) to an unknown situation by assuming that existing trends will continue or similar methods will be applicable
extrapolation	extension of a conclusion to a new situation with the assumption that existing trends will continue
F	
factual	relating to or based on facts; concerned with what is actually the case; actually occurring; having verified existence
familiar	well-acquainted; thoroughly conversant with; well known from long or close association; often encountered or experienced; common; (of materials, texts, skills or circumstances) having been the focus of learning experiences or previously encountered in prior learning activities
Faraday's law	a law stating that when the magnetic flux linking a circuit changes, an electromotive force (emf) is induced in the circuit proportional to the rate of change of the flux linkage (Tipler & Mosca 2003, Giancoli 2008)
feasible	capable of being achieved, accomplished or put into effect; reasonable enough to be believed or accepted; probable; likely
feature	distinctive attribute, characteristic, property or quality of evidence
Feynman diagram	graphical representation of particle interactions showing time along the horizontal axis and space along the vertical axis. The axis may be reversed, however not in this syllabus

Term	Explanation
field	a position in space where susceptible objects experience (are affected by) a force or acquire potential energy as they are 'worked' into that position; gravitational fields affect the mass of an object; electric fields affect electrically charged objects; magnetic fields affect ferromagnetic objects; electromagnetic fields affect electric charge carriers in matter (Tipler & Mosca 2003, Giancoli 2008)
findings	established facts or principles following systematic investigation of a subject
first law of thermodynamics	when energy passes, as work or heat, into or out of a system, the system's internal energy changes in accordance with the law of conservation of energy (Tipler & Mosca 2003, Giancoli 2008)
fluent	spoken or written with ease; able to speak or write smoothly, easily or readily; articulate; eloquent; in artistic performance, characteristic of a highly developed and excellently controlled technique; flowing; polished; flowing smoothly, easily and effortlessly
fluently	in a graceful and seemingly effortless manner; in a way that progresses smoothly and readily
force	a push or pull between objects that may cause one or both objects to change speed and/or the direction of their motion (i.e. accelerate) or change their shape; scientists identify four fundamental forces: gravitational, electromagnetic (involving both electrostatic and magnetic forces), the weak nuclear force and the strong nuclear force; all interactions between matter can be explained as the action of one, or a combination, of the four fundamental forces (Tipler & Mosca 2003, Giancoli 2008)
formative assessment	assessment whose major purpose is to improve teaching and student achievement
fragmented	disorganised; broken down; disjointed or isolated
frame of reference	the abstract coordinate system that defines location of the observer
frequency	equal to the number of waves that move past a given point in one second (symbol, f; SI unit, Hz) (Tipler & Mosca 2003, Giancoli 2008)
frequent	happening or occurring often at short intervals; constant, habitual, or regular
fundamental	forming a necessary base or core; of central importance; affecting or relating to the essential nature of something; part of a foundation or basis
fundamental forces	one of four forces that act between bodies of matter and that are mediated by one or more particles; they are, in order from strongest to weakest: the strong nuclear, the electromagnetic, the weak nuclear and the gravitational force. (ACARA 2015c, Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
G	
gamma radiation	extremely high-frequency electromagnetic radiation (high-frequency photons) emitted from the nucleus of some radionuclides (symbol, γ) (Tipler & Mosca 2003, Giancoli 2008)
gauge boson	carrier or exchange particles that govern particle interaction and the mediation of the four fundamental forces; there are four gauge bosons in the Standard Model: the gluon, photon, Z boson and W boson
General subject	a subject for which a syllabus has been developed by the QCAA with the following characteristics: results from courses developed from General syllabuses contribute to the QCE; General subjects have an external assessment component; results may contribute to ATAR calculations
generate	produce; create; bring into existence
genre conventions	agreed and acceptable conditions; a style or category
graphical representations	in science, a visual representation of the relationship between quantities plotted with reference to a set of axes; also known as a graph (ACARA 2015c)
gravitational field strength	the net force per unit mass at a particular point in the gravitational field (ACARA 2015c)
gravitational fields	the region of space surrounding a body in which another body experiences a force of gravitational attraction (Tipler & Mosca 2003, Giancoli 2008)
gravitational potential energy	the energy stored in an object as a result of its position relative to another object to which it is attracted by the force of gravity (abbreviation, GPE) (Tipler & Mosca 2003, Giancoli 2008)
H	
half-life	the time taken for half of the atoms in a sample of the material to undergo radioactive decay (Tipler & Mosca 2003, Giancoli 2008)
heat	the energy transferred from one system to another because of a difference in temperature (Tipler & Mosca 2003)
hypothesis	in science, a tentative explanation for an observed phenomenon, expressed as a precise and unambiguous statement that can be supported or refuted by experiment (ACARA 2015c)
hypothesise	formulate a supposition to account for known facts or observed occurrences; conjecture, theorise, speculate; especially on uncertain or tentative grounds
I	
identify	distinguish; locate, recognise and name; establish or indicate who or what someone or something is; provide an answer from a number of possibilities; recognise and state a distinguishing factor or feature

Term	Explanation
illogical	lacking sense or sound reasoning; contrary to or disregardful of the rules of logic; unreasonable
implement	put something into effect, e.g. a plan or proposal
implication	a likely consequence of something; a conclusion that may be drawn though it is implied rather than explicit
implicit	implied, rather than expressly stated; not plainly expressed; capable of being inferred from something else
improbable	not probable; unlikely to be true or to happen; not easy to believe
improvements	in science, modifications to an investigation that mitigate the limitations of the evidence, method or design
impulse	the change in momentum of an object; equals the product of a force and the time interval over which the force acts (Tipler & Mosca 2003, Giancoli 2008)
inaccurate	not accurate
inadequate	not satisfactory or acceptable in quality and/or quantity to the requirements of the situation
inappropriate	not suitable or proper in the circumstances
inconsistent	lacking agreement, as one thing with another, or two or more things in relation to each other; at variance; not consistent; not in keeping; not in accordance; incompatible, incongruous
incorrect	not conforming to fact or truth
independent	thinking or acting for oneself, not influenced by others
in-depth	comprehensive and with thorough coverage; extensive or profound; well-balanced or fully developed
ineffective	not producing a result, or not producing any significant result; not producing the intended, desired or expected result
inelastic collision	a collision in which kinetic energy is not conserved (Tipler & Mosca 2003, Giancoli 2008)
inertial frame of reference	any frame of reference with respect to which the acceleration of the object of observation remains zero (Tipler & Mosca 2003)
infer	derive or conclude something from evidence and reasoning, rather than from explicit statements; listen or read beyond what has been literally expressed; imply or hint at
informed	knowledgeable; learned; having relevant knowledge; being conversant with the topic; based on an understanding of the facts of the situation (of a decision or judgment)
innovative	new and original; introducing new ideas; original and creative in thinking

Term	Explanation
insightful	showing understanding of a situation or process; understanding relationships in complex situations; informed by observation and deduction
instrument-specific marking guide	ISMG; a tool for marking that describes the characteristics evident in student responses and aligns with the identified objectives for the assessment (see 'assessment objectives')
insufficient	not enough; inadequate for the purpose
integral	*adjective* necessary for the completeness of the whole; essential or fundamental; *noun* in mathematics, the result of integration; an expression from which a given function, equation, or system of equations is derived by differentiation
intended	designed; meant; done on purpose; intentional
intensity	the average rate of flow of energy per unit area (Tipler & Mosca 2003, Giancoli 2008)
interference	the combination of two or more waves to form a resultant wave (Tipler & Mosca 2003)
internal assessment	assessments that are developed by schools; summative internal assessments are endorsed by the QCAA before use in schools and results externally confirmed; contributes towards a student's final result
internal energy	the total potential energy and kinetic energy of the particles in a system (Tipler & Mosca 2003, Giancoli 2008)
interpret	use knowledge and understanding to recognise trends and draw conclusions from given information; make clear or explicit; elucidate or understand in a particular way; bring out the meaning of, e.g. a dramatic or musical work, by performance or execution; bring out the meaning of an artwork by artistic representation or performance; give one's own interpretation of; identify or draw meaning from, or give meaning to, information presented in various forms, such as words, symbols, pictures or graphs
invalid	not sound, just or well-founded; not having a sound basis in logic or fact (of an argument or point); not reasonable or cogent; not able to be supported; not legitimate or defensible; not applicable
investigate	carry out an examination or formal inquiry in order to establish or obtain facts and reach new conclusions; search, inquire into, interpret and draw conclusions about data and information

Term	Explanation
investigation	an assessment technique that requires students to research a specific problem, question, issue, design challenge or hypothesis through the collection, analysis and synthesis of primary and/or secondary data; it uses research or investigative practices to assess a range of cognitions in a particular context; an investigation occurs over an extended and defined period of time in science, a scientific process of answering a question, exploring an idea or solving a problem that requires activities such as planning a course of action, collecting data, interpreting data, reaching a conclusion and communicating these activities (ACARA 2015c)
ionisation	the process by which an atom or molecule acquires a negative or positive charge by gaining or losing electrons
irrelevant	not relevant; not applicable or pertinent; not connected with or relevant to something
ISMG	instrument-specific marking guide; a tool for marking that describes the characteristics evident in student responses and aligns with the identified objectives for the assessment (see 'assessment objectives')
isolated	detached, separate, or unconnected with other things; one-off; something set apart or characterised as different in some way
J	
judge	form an opinion or conclusion about; apply both procedural and deliberative operations to make a determination
justified	sound reasons or evidence are provided to support an argument, statement or conclusion
justify	give reasons or evidence to support an answer, response or conclusion; show or prove how an argument, statement or conclusion is right or reasonable
K	
Kepler's laws of planetary motion	the first law states that all planets move about the Sun in elliptical orbits, having the Sun as one of the foci; the second law states that a radius vector joining any planet to the Sun sweeps out equal areas in equal lengths of time; the third law states that the squares of the sidereal periods of the planets are directly proportional to the cubes of their mean distance from the Sun (Tipler & Mosca 2003)
kinetic energy	the energy resulting from the movement of an object. When associated with temperature, kinetic energy is associated with the motion of particles in a substance (symbol, E_k; SI unit, J) (Tipler & Mosca 2003, Giancoli 2008)
kinetic particle model of matter	a model in which matter is made up of particles that are constantly moving (Tipler & Mosca 2003, Giancoli 2008)
Kirchhoff's current law	at any node in an electrical circuit, electric charge is conserved such that the sum of the electric currents flowing into a node is equal to the sum of electric currents flowing out of that node (Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
Kirchhoff's voltage law	the energy inputs in a circuit equal the sum of energy output from loads in the circuit such that the directed sum of the electrical potential differences around any closed network is zero (Tipler & Mosca 2003, Giancoli 2008)
L	
law	a statement describing invariable relationships between phenomena in specified conditions, frequently expressed mathematically (ACARA 2015c)
law of conservation of electric charge	the total electric charge of an isolated system remains constant regardless of changes within the system (Tipler & Mosca 2003, Giancoli 2008)
law of conservation of energy	the total energy of a system remains constant; energy can neither be created nor destroyed, rather, it transforms from one form to another (Tipler & Mosca 2003, Giancoli 2008)
law of conservation of momentum	states that for two objects colliding in an isolated system, the total momentum before and after the collision is equal (Tipler & Mosca 2003, Giancoli 2008)
learning area	a grouping of subjects, with related characteristics, within a broad field of learning, e.g. the Arts, sciences, languages
length contraction	an observer at rest relative to a moving object would observe the moving object to be shorter along the dimension of motion
Lenz's law	states that the direction of an induced electric current always opposes the change in the circuit or the magnetic field that produces it (Tipler & Mosca 2003, Giancoli 2008)
lepton number	a conserved quantum number defined by $L = n_l - n_{\bar{l}}$, where n_l is the number of leptons and $n_{\bar{l}}$ is the number of antileptons (Tipler & Mosca 2003, Giancoli 2008)
leptons	particles that are governed by the weak nuclear force and, since they have charge, are also influenced by electromagnetism; there are six leptons in the Standard Model: electron, electron neutrino, muon, muon neutrino, tau and tau neutrino
limitation	a weak point or disadvantage that makes evidence less effective; limitations of *data/evidence* relate to how appropriate it is to use the data/evidence to address a particular research questions. Limitations of the data/evidence are related to the parameters of the inquiry which in turn define the extent to which the data can be used
linear motion	straight line motion or an idealisation of approximately straight line motion when an object moves from one place to another (Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
link	anything serving to connect one part or thing with another
logical	rational and valid; internally consistent; reasonable; reasoning in accordance with the principles/rules of logic or formal argument; characterised by or capable of clear, sound reasoning; (of an action, decision, etc.) expected or sensible under the circumstances
logically	according to the rules of logic or formal argument; in a way that shows clear, sound reasoning; in a way that is expected or sensible
longitudinal wave	a wave where the direction of oscillation of particles is parallel to the direction of energy transfer or wave movement (Tipler & Mosca 2003, Giancoli 2008)
M	
magnetic field	a region of space near a magnet, electric current or moving electrically charged particle in which a magnetic force acts on any other magnet, electric current or moving electrically charged particle (Tipler & Mosca 2003, Giancoli 2008)
magnetic flux	a measurement of the total magnetic field that passes through a given area; a measure of the number of magnetic field lines passing through the given area (symbol, ϕ; SI unit, Wb) (Tipler & Mosca 2003, Giancoli 2008)
magnetic flux density	the strength of a magnetic field or the number of magnetic field lines per unit area (symbol, B; SI unit, Wb/m^2 or T) (Tipler & Mosca 2003, Giancoli 2008)
make decisions	select from available options; weigh up positives and negatives of each option and consider all the alternatives to arrive at a position
management	handling, direction or control
manipulate	adapt or change to suit one's purpose
mass defect	the difference between the mass of an intact nucleus and the sum of the masses of the individual nucleons of which it is made (Tipler & Mosca 2003, Giancoli 2008)
mass number	the total number of nucleons in an element’s nucleus, A, i.e. the number of protons plus the number of neutrons (Tipler & Mosca 2003, Giancoli 2008)
mass–energy equivalence relationship	$\Delta E = \Delta mc^2$
material	a substance with particular qualities or that is used for specific purposes
matter	a physical substance; anything that has mass and occupies space
measurement discrepancy	the difference between the measured result and a currently accepted or standard value of a quantity (ACARA 2015c)

Term	Explanation
measurement uncertainty	the measure of doubt associated with the measured result due to imprecision; it may be represented as an absolute uncertainty or as a percentage uncertainty (Taylor 1982)
mechanical wave	a wave that requires a medium to propagate; mechanical waves may oscillate the medium or oscillate the pressure within the medium (Tipler & Mosca 2003, Giancoli 2008)
mechanical work	the transfer of energy to or from an object by the action of a force over a distance (Tipler & Mosca 2003, Giancoli 2008)
media texts	spoken, print, graphic or electronic communications with a public audience; media texts can be found in newspapers, magazines and on television, film, radio, computer software and the internet (ACARA 2015c)
mental procedures	a domain of knowledge in Marzano's taxonomy, and acted upon by the cognitive, metacognitive and self-systems; sometimes referred to as 'procedural knowledge' there are three distinct phases to the acquisition of mental procedures — the cognitive stage, the associative stage, and the autonomous stage; the two categories of mental procedures are skills (single rules, algorithms and tactics) and processes (macroprocedures)
mesons	subatomic particles composed of one quark and one antiquark (Tipler & Mosca 2003, Giancoli 2008)
methodical	performed, disposed or acting in a systematic way; orderly; characterised by method or order; performed or carried out systematically
methodology	a systematic, ordered approach to gathering data in a scientific experiment or investigation
minimal	least possible; small, the least amount; negligible
model	in science, a representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea (ACARA 2015c)
modifications	in science, changes to methodology to extend, refine or redirect the research focus
modify	change the form or qualities of; make partial or minor changes to something
momentum	the product of an object's mass and its velocity (Tipler & Mosca 2003, Giancoli 2008)
multimodal	uses a combination of at least two modes (e.g. spoken, written), delivered at the same time, to communicate ideas and information to a live or virtual audience, for a particular purpose; the selected modes are integrated so that each mode contributes significantly to the response

Term	Explanation
N	
narrow	limited in range or scope; lacking breadth of view; limited in amount; barely sufficient or adequate; restricted
natural frequency	the frequency at which an object will resonate when stimulated. It is independent of the size of the stimulus, depending solely upon the object's size, shape and composition (Tipler & Mosca 2003, Giancoli 2008)
natural radioactive decay	the process by which the nucleus of an unstable atom loses energy by emitting radiation, including alpha particles, beta particles, gamma rays and electrons without artificial stimulus to do so
neutron	a subatomic particle with neutral electric charge
Newton's law of universal gravitation	the force of attraction between each pair of point particles that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them (Tipler & Mosca 2003)
Newton's three laws of motion	the first law states that an object at rest stays at rest unless acted on by an external force; the second law states that the direction of the acceleration of an object is in the direction of the net external force acting on it and proportional to the size of the force; the third law states that forces always occur in equal and opposite pairs (Tipler & Mosca 2003, Giancoli 2008)
node	point in a medium that is not displaced as a wave is propagated through it (Tipler & Mosca 2003)
non-ohmic resistor	a resistor that does not behave according to Ohm's law
normal force	the force acting along an imaginary line drawn perpendicular to the surface (Tipler & Mosca 2003, Giancoli 2008)
nuanced	showing a subtle difference or distinction in expression, meaning, response, etc.; finely differentiated; characterised by subtle shades of meaning or expression; a subtle distinction, variation or quality; sensibility to, awareness of, or ability to express delicate shadings, as of meaning, feeling, or value
nuclear fission	the process in which a large unstable nucleus splits, forming two (or more) smaller, more stable nuclei and releasing neutrons and energy (Tipler & Mosca 2003, Giancoli 2008)
nuclear fusion	a nuclear reaction in which two or more atomic nuclei combine to form one or more different, heavier atomic nuclei and subatomic particles (Tipler & Mosca 2003, Giancoli 2008)
nuclear model	this model describes the atom as having a small positively charged core surrounded by negatively charged particles called electrons
nucleon	the particles (protons and neutrons) that make up the nucleus of an atom (Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
nuclide	the range of atomic nuclei associated with a particular atom, which is defined by the atomic number and the various isotopes of that atom as identified by the mass number (Tipler & Mosca 2003, Giancoli 2008)
O	
objectives	see 'syllabus objectives', 'unit objectives', 'assessment objectives'
obvious	clearly perceptible or evident; easily seen, recognised or understood
Ohm's law	states that electric current is proportional to voltage and inversely proportional to resistance (Tipler & Mosca 2003, Giancoli 2008)
ohmic resistor	a resistor that behaves according to Ohm's law
optimal	best, most favourable, under a particular set of circumstances
organise	arrange, order; form as or into a whole consisting of interdependent or coordinated parts, especially for harmonious or united action
organised	systematically ordered and arranged; having a formal organisational structure to arrange, coordinate and carry out activities
outcome	result of something; a consequence
outlier	a value that 'lies outside' (is much smaller or larger than) most of the other values in a set of data
outstanding	exceptionally good; clearly noticeable; prominent; conspicuous; striking
P	
partial	not total or general; existing only in part; attempted, but incomplete
particular	distinguished or different from others or from the ordinary; noteworthy
pattern	a repeated occurrence or sequence (ACARA 2015c)
percentage error	a mathematical indication of how accurate the measurements were with respects to the accepted value of a quantity $\text{percentage error } (\%) = \left\lvert \frac{\text{measured value} - \text{true value}}{\text{true value}} \right\rvert \times 100$ (Taylor 1982)
perceptive	having or showing insight and the ability to perceive or understand; discerning (see also 'discriminating')
performance	an assessment technique that requires students to demonstrate a range of cognitive, technical, creative and/or expressive skills and to apply theoretical and conceptual understandings, through the psychomotor domain; it involves student application of identified skills when responding to a task that involves solving a problem, providing a solution or conveying meaning or intent; a performance is developed over an extended and defined period of time

Term	Explanation
period	the amount of time one cycle or one event takes to occur; the length of time taken for one wavelength to pass a given point; in circular motion, period refers to the time taken to complete one revolution (symbol, T; SI unit, s) (Tipler & Mosca 2003, Giancoli 2008)
persuasive	capable of changing someone's ideas, opinions or beliefs; appearing worthy of approval or acceptance; (of an argument or statement) communicating reasonably or credibly (see also 'convincing')
pertinent	relevant and applicable to a particular matter
perusal time	time allocated in an assessment to reading items and tasks and associated assessment materials; no writing is allowed; students may not make notes and may not commence responding to the assessment in the response space/book
phenomena	events that are not artificial and can be observed through the senses or can be scientifically described or explained
photon	a quantum of all forms of electromagnetic radiation; a gauge boson responsible for mediating the electromagnetic force
Planck's constant	a fundamental constant used in quantum mechanics (symbol, h; SI unit, Js) (Tipler & Mosca 2003, Giancoli 2008)
planning time	time allocated in an assessment to planning how to respond to items and tasks and associated assessment materials; students may make notes but may not commence responding to the assessment in the response space/book; notes made during planning are not collected, nor are they graded or used as evidence of achievement
polarisation	the linear polarisation of light refers to light in the form of a plane wave in space rather than composed of two plane waves of equal amplitude differing in phase by 90°
polished	flawless or excellent; performed with skilful ease
postulates of special relativity	the first postulate states that the laws of physics are the same in all inertial frames of reference; the second postulate states that the speed of light in a vacuum has the same value c in all inertial frames of reference
power	the rate at which work is done or the rate at which energy is transferred or transformed (symbol, P; SI unit, W) (Tipler & Mosca 2003, Giancoli 2008)
power dissipation	a measure of the rate at which energy is lost from an electrical system; power dissipation of a resistor can be calculated using the formula, $P = VI$ (Tipler & Mosca 2003, Giancoli 2008)
practical	in science, an activity that produces primary data
precise	definite or exact; definitely or strictly stated, defined or fixed; characterised by definite or exact expression or execution

Term	Explanation
precision	accuracy; exactness; exact observance of forms in conduct or actions in science, exactness; how close two or more measurements of the same object or phenomena are to each other
predict	give an expected result of an upcoming action or event; suggest what may happen based on available information
primary data	data collected directly by a person or group (ACARA 2015c)
primary source	information created by the person or persons directly involved in a study, investigation or experiment or observing an event (ACARA 2015c)
process	in science, to collect and manipulate data to produce meaningful information; operate on a set of data to extract the required information in an appropriate form such as tables or graphs
product	an assessment technique that focuses on the output or result of a process requiring the application of a range of cognitive, physical, technical, creative and/or expressive skills, and theoretical and conceptual understandings; a product is developed over an extended and defined period of time
proficient	well advanced or expert in any art, science or subject; competent, skilled or adept in doing or using something
project	an assessment technique that focuses on a problem-solving process requiring the application of a range of cognitive, technical and creative skills and theoretical understandings; the response is a coherent work that documents the iterative process undertaken to develop a solution and includes written paragraphs and annotations, diagrams, sketches, drawings, photographs, video, spoken presentations, physical prototypes and/or models; a project is developed over an extended and defined period of time
proper length	the length measured in the frame of reference in which the object is at rest (Tipler & Mosca 2003, Giancoli 2008)
proper time interval	the time interval measured in the frame of reference in which the object is at rest (Tipler & Mosca 2003, Giancoli 2008)
property	attribute of an object or material, normally used to describe attributes common to a group
proportionality	describes the manner in which one variable changes if the other is changed
propose	put forward (e.g. a point of view, idea, argument, suggestion) for consideration or action
proton	a subatomic particle with a positive electric charge
prove	use a sequence of steps to obtain the required result in a formal way

Term	Explanation
psychomotor procedures	a domain of knowledge in Marzano’s taxonomy, and acted upon by the cognitive, metacognitive and self-systems; these are physical procedures used to negotiate daily life and to engage in complex physical activities; the two categories of psychomotor procedures are skills (foundational procedures and simple combination procedures) and processes (complex combination procedures)
purposeful	having an intended or desired result; having a useful purpose; determined; resolute; full of meaning; significant; intentional
Q	
QCE	Queensland Certificate of Education
qualitative data	information that is not numerical in nature
quality of evidence	the standard of evidence, as measured against relevant criteria
quantitative data	numerical information (Taylor 1982)
quantity	scientific quantity is something having magnitude, size, extent, amount or the like
quarks	subatomic particles governed by the strong nuclear force that constitute hadrons; there are six quarks in the Standard Model: the up, down, charm, strange, top and bottom quark
R	
radiation	the emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles, which cause ionisation (Tipler & Mosca 2003, Giancoli 2008)
radioactive	a nucleus with excess energy that must be relieved by emitting the excess energy (Tipler & Mosca 2003, Giancoli 2008)
radionuclide	a radioactive nuclide (Tipler & Mosca 2003, Giancoli 2008)
random error	uncontrollable effects of the measurement equipment, procedure and environment on a measurement result; the magnitude of random error for a measurement result can be estimated by finding the spread of values around the average of independent, repeated measurements of the quantity (ACARA 2015c)
rarefaction	a region in a longitudinal wave where the particles are furthest apart (Tipler & Mosca 2003, Giancoli 2008)
rationale	a set of reasons, or logical basis for a course of action or decision
raw data	unprocessed and/or unanalysed data; data that has been collected without any additional processing (Taylor 1982)
realise	create or make (e.g. a musical, artistic or dramatic work); actualise; make real or concrete; give reality or substance to
reasonable	endowed with reason; having sound judgment; fair and sensible; based on good sense; average; appropriate, moderate

Term	Explanation
reasoned	logical and sound; based on logic or good sense; logically thought out and presented with justification; guided by reason; well-grounded; considered
recall	remember; present remembered ideas, facts or experiences; bring something back into thought, attention or into one's mind
recognise	identify or recall particular features of information from knowledge; identify that an item, characteristic or quality exists; perceive as existing or true; be aware of or acknowledge
redirect	in science, to redirect an experiment is to modify the methodology to gain further insight into the phenomena observed in the original experiment
referencing conventions	agreed, consistent ways of referencing a source of information
refine	in science, to refine an experiment is to modify the methodology to obtain more accurate or precise data
refined	developed or improved so as to be precise, exact or subtle
reflect on	think about deeply and carefully
reflection	when incident waves at a boundary change direction returning into the same medium according to the law of reflection (Tipler & Mosca 2003, Giancoli 2008)
refraction	when incident waves at a boundary change direction and speed when passing into another medium according to Snell's law of refraction (Tipler & Mosca 2003, Giancoli 2008)
rehearsed	practised; previously experienced; practised extensively
related	associated with or linked to
relationship	scientific relationships are a connection or association between ideas or between components of systems and structures (ACARA 2015c)
relativistic length	the length measured in the frame of reference in which the object is in motion (symbol, L; SI unit, m) (Tipler & Mosca 2003, Giancoli 2008)
relativistic momentum	the momentum of an object when measured in the frame of reference in which the object is in motion (symbol, p_v; SI unit, Ns) (Tipler & Mosca 2003, Giancoli 2008)
relativistic time interval	the time interval measured in the frame of reference in which the object is in motion (symbol, t; SI unit, s) (Tipler & Mosca 2003, Giancoli 2008)
relevance	being related to the matter at hand
relevant	bearing upon or connected with the matter in hand; to the purpose; applicable and pertinent; having a direct bearing on
reliable	constant and dependable or consistent and repeatable

Term	Explanation
reliability	in science, the likelihood that another experimenter will obtain the same results (or very similar results) if they perform exactly the same experiment under the same conditions (ACARA 2015c, Taylor 1982)
repetitive	containing or characterised by repetition, especially when unnecessary or tiresome
report	a written account of an investigation
reporting	providing information that succinctly describes student performance at different junctures throughout a course of study
representation	in science, verbal, visual, physical or mathematical demonstration of understanding of a science concept or concepts; a concept can be represented in a range of ways and using multiple modes (ACARA 2015c)
reproducibility	similar to repeatability, however, it refers to how well independent results agree when obtained using the same methodology and materials but under different conditions (Taylor 1982)
research	to locate, gather, record and analyse information to develop understanding (ACARA 2015c)
research ethics	norms of conduct that determine ethical research behaviour; research ethics are governed by principles such as honesty, objectivity, integrity, openness and respect for intellectual property and include consideration of animal ethics (ACARA 2015c)
research question	a question that directs the scientific inquiry activity; it focuses the research investigation or student experiment, informing the direction of the research and guiding all stages of inquiry, analysis, interpretation and evaluation
resistance	the ratio of the voltage applied to the electric current that flows through it (Tipler & Mosca 2003, Giancoli 2008)
resolve	in the Arts, consolidate and communicate intent through a synthesis of ideas and application of media to express meaning
resonance	when a vibrating system or external force drives another system to oscillate with greater energy at a particular frequency; resonance occurs when a system is forced to vibrate at one of its natural frequencies (Tipler & Mosca 2003, Giancoli 2008)
rest mass	the mass of an object when measured in the same reference frame as the observer (Tipler & Mosca 2003, Giancoli 2008)
risk assessment	evaluations performed to identify, assess and control hazards in a systematic way that is consistent, relevant and applicable to all school activities; requirements for risk assessments related to particular activities will be determined by jurisdictions, schools or teachers as appropriate (ACARA 2015c)
routine	often encountered, previously experienced; commonplace; customary and regular; well-practised; performed as part of a regular procedure, rather than for a special reason

Term	Explanation
rudimentary	relating to rudiments or first principles; elementary; undeveloped; involving or limited to basic principles; relating to an immature, undeveloped or basic form
S	
safe	secure; not risky
scalar	a quantity that has a magnitude but no direction
scientific language	terminology that has specific meaning in a scientific context
scrutinise	to examine closely or critically
secondary data	data collected by a person or group other than the person or group using the data (ACARA 2015c, Macquarie 1981)
secondary source	information that has been compiled from records of primary sources by a person or persons not directly involved in the primary event (ACARA 2015c)
secure	sure; certain; able to be counted on; self-confident; poised; dependable; confident; assured; not liable to fail
select	choose in preference to another or others; pick out
sensitive	capable of perceiving with a sense or senses; aware of the attitudes, feelings or circumstances of others; having acute mental or emotional sensibility; relating to or connected with the senses or sensation
sequence	place in a continuous or connected series; arrange in a particular order
show	provide the relevant reasoning to support a response
significant	important; of consequence; expressing a meaning; indicative; includes all that is important; sufficiently great or important to be worthy of attention; noteworthy; having a particular meaning; indicative of something
significant figures	the use of place value to represent a measurement result accurately and precisely (ACARA 2015c)
simple	easy to understand, deal with and use; not complex or complicated; plain; not elaborate or artificial; may concern a single or basic aspect; involving few elements, components or steps
simplistic	characterised by extreme simplification, especially if misleading; oversimplified
simulation	a representation of a process, event or system that imitates a real or idealised situation (ACARA 2015c)
simultaneity	the relation between two events assumed to happen at the same time in a frame of reference

Term	Explanation
sketch	execute a drawing or painting in simple form, giving essential features but not necessarily with detail or accuracy; in mathematics, represent by means of a diagram or graph; the sketch should give a general idea of the required shape or relationship and should include features
skilful	having technical facility or practical ability; possessing, showing, involving or requiring skill; expert, dexterous; demonstrating the knowledge, ability or training to perform a certain activity or task well; trained, practised or experienced
skilled	having or showing the knowledge, ability or training to perform a certain activity or task well; having skill; trained or experienced; showing, involving or requiring skill
Snell's law	$n_1 sin(i) = n_2 sin(r)$ (Tipler & Mosca 2003, Giancoli 2008)
solve	find an answer to, explanation for, or means of dealing with (e.g. a problem); work out the answer or solution to (e.g. a mathematical problem); obtain the answer/s using algebraic, numerical and/or graphical methods
sophisticated	of intellectual complexity; reflecting a high degree of skill, intelligence, etc.; employing advanced or refined methods or concepts; highly developed or complicated
source	any piece of scientific literature or text from which scientific evidence is drawn
specific	clearly defined or identified; precise and clear in making statements or issuing instructions; having a special application or reference; explicit, or definite; peculiar or proper to something, as qualities, characteristics, effects, etc.
specific heat capacity	the amount of thermal energy transfer necessary to raise the temperature of one kilogram of a substance by one degree (symbol, c; SI unit, J kg^{-1} K^{-1}) (Tipler & Mosca 2003, Giancoli 2008)
specific latent heat	the amount of energy transfer necessary to change the state of one kilogram of a substance with no change in its temperature; the term 'latent heat of fusion' (symbol, L_f; SI unit, J kg^{-1}) refers to the amount of energy transfer necessary to change one kilogram of a substance from solid to liquid; the term 'latent heat of vaporisation' (symbol, L_v; SI unit, J kg^{-1}) refers to the amount of energy transfer necessary to change one kilogram of a substance from liquid to gas (Tipler & Mosca 2003, Giancoli 2008)
sporadic	happening now and again or at intervals; irregular or occasional; appearing in scattered or isolated instances
standing wave	waves with stationary vibration patterns formed due to the superposition of waves with particular frequencies (Tipler & Mosca 2003)

Term	Explanation
statement	a communication or declaration setting forth facts, particulars; an expression
straightforward	without difficulty; uncomplicated; direct; easy to do or understand
strong nuclear force	one of the four fundamental forces; the strong nuclear force acts over small distances in the nucleus to hold the nucleons together against the repulsive electrostatic forces exerted between the protons; the strong nuclear force is mediated by gluons (Tipler & Mosca 2003, Giancoli 2008)
structure	*verb* give a pattern, organisation or arrangement to; construct or arrange according to a plan; *noun* in languages, arrangement of words into larger units, e.g. phrases, clauses, sentences, paragraphs and whole texts, in line with cultural, intercultural and textual conventions
structured	organised or arranged so as to produce a desired result
subject	a branch or area of knowledge or learning defined by a syllabus; school subjects are usually based in a discipline or field of study (see also ‘course’)
subject matter	the subject-specific body of information, mental procedures and psychomotor procedures that are necessary for students’ learning and engagement within that subject
substantial	of ample or considerable amount, quantity, size, etc.; of real worth or value; firmly or solidly established; of real significance; reliable; important, worthwhile
substantiated	established by proof or competent evidence
subtle	fine or delicate in meaning or intent; making use of indirect methods; not straightforward or obvious
successful	achieving or having achieved success; accomplishing a desired aim or result
succinct	expressed in few words; concise; terse; characterised by conciseness or brevity; brief and clear
sufficient	enough or adequate for the purpose
suitable	appropriate; fitting; conforming or agreeing in nature, condition, or action
summarise	give a brief statement of a general theme or major point/s; present ideas and information in fewer words and in sequence
summative assessment	assessment whose major purpose is to indicate student achievement; summative assessments contribute towards a student’s subject result

Term	Explanation
superficial	concerned with or comprehending only what is on the surface or obvious; shallow; not profound, thorough, deep or complete; existing or occurring at or on the surface; cursory; lacking depth of character or understanding; apparent and sometimes trivial
superposition	when two or more waves overlap in space, the resultant wave is the algebraic sum of the individual waves (Tipler & Mosca 2003, Giancoli 2008)
supported	corroborated; given greater credibility by providing evidence
sustained	carried on continuously, without interruption, or without any diminishing of intensity or extent
syllabus	a document that prescribes the curriculum for a course of study
syllabus objectives	outline what the school is required to teach and what students have the opportunity to learn; described in terms of actions that operate on the subject matter; the overarching objectives for a course of study (see also 'unit objectives', 'assessment objectives')
symbolise	represent or identify by a symbol or symbols
synthesise	combine different parts or elements (e.g. information, ideas, components) into a whole, in order to create new understanding
system	a group of interacting objects, materials or processes that form an integrated whole; systems can be open or closed (ACARA 2015c)
systematic	done or acting according to a fixed plan or system; methodical; organised and logical; having, showing, or involving a system, method, or plan; characterised by system or method; methodical; arranged in, or comprising an ordered system
systematic error	an error that is affected by the accuracy of a measurement process that causes readings to deviate from the accepted value by a consistent amount each time a measurement is made (Taylor 1982)
T	
temperature	the degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale, e.g. the Celsius temperature scale (Tipler & Mosca 2003, Giancoli 2008)
test	take measures to check the quality, performance or reliability of something
theory	in science, a set of concepts, claims and/or laws that can be used to explain and predict a wide range of related observed or observable phenomena; theories are typically founded on clearly identified assumptions, are testable, produce reproducible results and have explanatory power (ACARA 2015c)

Term	Explanation
thermal energy	the internal energy present in a system due to its temperature (symbol, U; SI unit, J); transfer of thermal energy when heating or cooling a substance has the symbol Q in the equation $Q = mc\Delta T$ (Tipler & Mosca 2003, Giancoli 2008)
thermal equilibrium	the condition of a system in which there is no net exchange of thermal energy between any of its components, i.e. the components have the same temperature and the average kinetic energy of their particles is equal; this relates to the zeroth law of thermodynamics (Tipler & Mosca 2003, Giancoli 2008)
thermodynamics	the study of heating processes and their relationships with various forms of energy and work; concerned with characteristics of energy such as temperature, entropy and pressure and their interrelationships (Tipler & Mosca 2003, Giancoli 2008)
thorough	carried out through, or applied to the whole of something; carried out completely and carefully; including all that is required; complete with attention to every detail; not superficial or partial; performed or written with care and completeness; taking pains to do something carefully and completely
thought experiments	a process whereby the consequences of a principle, postulate or theory are examined without necessarily undertaking the experiment
thoughtful	occupied with, or given to thought; contemplative; meditative; reflective; characterised by or manifesting thought
threshold frequency	the minimum frequency of a photon that can eject an electron from a surface (Tipler & Mosca 2003, Giancoli 2008)
time dilation	the difference of elapsed time between two events as measured by observers moving relative to each other (Tipler & Mosca 2003, Giancoli 2008)
topic	a division of, or sub-section within a unit; all topics/sub-topics within a unit are interrelated
total internal reflection	the phenomenon whereby all energy is reflected inside a medium due to the incident angle of the wave being greater than the critical angle (Tipler & Mosca 2003, Giancoli 2008)
transverse wave	a wave where the direction of oscillation of particles is perpendicular to the direction of energy transfer (Tipler & Mosca 2003, Giancoli 2008)
trend	general direction in which something is changing (ACARA 2015c)
trough	the lowest part or point of a wave (Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
U	
uncertainty	range of values for a measurement result, taking account of the likely values that could be attributed to the measurement result given the measurement equipment, procedure and environment (ACARA 2015c); indicators of uncertainty can include (but are not limited to) percentage and/or absolute measurement uncertainty, confidence intervals, inferential statistics, statistical measures of spread (e.g. range, standard deviation)
unclear	not clear or distinct; not easy to understand; obscure
understand	perceive what is meant by something; grasp; be familiar with (e.g. an idea); construct meaning from messages, including oral, written and graphic communication
understanding	perception of what is meant by something
uneven	unequal; not properly corresponding or agreeing; irregular; varying; not uniform; not equally balanced
unfamiliar	not previously encountered; situations or materials that have not been the focus of prior learning experiences or activities
unified atomic mass unit	a unit of mass used for very small masses (unit, u), equal to 1.66×10^{-27} kg (Tipler & Mosca 2003, Giancoli 2008)
uniform circular motion	the motion of an object travelling at a constant speed in a circle
unit	a defined amount of subject matter delivered in a specific context or with a particular focus; it includes unit objectives particular to the unit, subject matter and assessment direction
unit objectives	drawn from the syllabus objectives and contextualised for the subject matter and requirements of a particular unit; they are assessed at least once in the unit (see also ‘syllabus objectives’, ‘assessment objectives’)
universal law	the applicability of the relationships expressed in the law extends from Earth to the known universe (Feynman 1964)
unrelated	having no relationship; unconnected
use	operate or put into effect; apply knowledge or rules to put theory into practice
V	
vague	not definite in statement or meaning; not explicit or precise; not definitely fixed, determined or known; of uncertain, indefinite or unclear character or meaning; not clear in thought or understanding; couched in general or indefinite terms; not definitely or precisely expressed; deficient in details or particulars; thinking or communicating in an unfocused or imprecise way

Term	Explanation
valid	sound, just or well-founded; authoritative; having a sound basis in logic or fact (of an argument or point); reasonable or cogent; able to be supported; legitimate and defensible; applicable
validity	in science, the extent to which tests measure what was intended; the extent to which data, inferences and actions produced from tests and other processes are accurate (ACARA 2015c)
variable	*adjective* apt or liable to vary or change; changeable; inconsistent; (readily) susceptible or capable of variation; fluctuating, uncertain; *noun* in mathematics, a symbol, or the quantity it signifies, that may represent any one of a given set of number and other objects in science, a factor that can be changed, kept the same or measured in an investigation, e.g. time, distance, light, temperature
variety	a number or range of things of different kinds, or the same general class, that are distinct in character or quality; (of sources) a number of different modes or references
vector	a quantity that has both magnitude and direction; a vector may be represented pictorially by an arrowed line segment (→) and symbolically as $\vec{a}$ or $\underline{a}$ (Tipler & Mosca 2003, Giancoli 2008)
velocity	the rate of change of displacement of an object (symbol, v; SI unit, m/s); if the rate of change is measured at an instant in time then this is an instantaneous velocity; if the rate of change is calculated using the formula $\text{velocity} = \frac{\text{displacement}}{\text{time}}$, then this is average velocity (Tipler & Mosca 2003, Giancoli 2008)
visual representations	in science, an image that shows relationships within scientific evidence
W	
wave model of light	uses the characteristics of waves such as wavelength, frequency and speed to describe the behaviour of light such as interference and refraction (Tipler & Mosca 2003, Giancoli 2008)
wavelength	the distance between corresponding points on successive waves (symbol, λ; SI unit, m) (Tipler & Mosca 2003, Giancoli 2008)
weak nuclear force	one of the four fundamental forces; the weak nuclear force is responsible for radioactive decay and is mediated by W and Z bosons (Tipler & Mosca 2003, Giancoli 2008)
wide	of great range or scope; embracing a great number or variety of subjects, cases, etc.; of full extent
with expression	in words, art, music or movement, conveying or indicating feeling, spirit, character, etc.; a way of expressing or representing something; vivid, effective or persuasive communication
work function	the minimum energy required to remove an electron from a solid (symbol, W; SI unit, J) (Tipler & Mosca 2003, Giancoli 2008)

Term	Explanation
Z	
zeroth law of thermodynamics	the transfer of energy from a system with higher temperature to a system with lower temperature until thermal equilibrium is reached (Tipler & Mosca 2003, Giancoli 2008)

7 References

Abrams, E, Southerland, S & Silva, P 2008, Inquiry in the Classroom: Realities and opportunities, Information Age Publishing, North Carolina.

Australian Curriculum, Assessment and Reporting Authority (ACARA) 2009, Shape of the Australian Curriculum: Science, National Curriculum Board, Commonwealth of Australia, http://docs.acara.edu.au/resources/Australian_Curriculum_-_Science.pdf

——2015a, The Australian Curriculum: Literacy, Version 8.2, https://australiancurriculum.edu.au/f-10-curriculum/general-capabilities/literacy/

——2015b, The Australian Curriculum: Numeracy, Version 8.2, https://australiancurriculum.edu.au/f-10-curriculum/general-capabilities/numeracy/

——2015c, The Australian Curriculum: Senior Secondary Curriculum Science Glossary, Version 8.2, www.australiancurriculum.edu.au/senior-secondary-curriculum/science/glossary.

Binkley, M, Erstad, O, Herman, J, Raizen, S, Riplay, M, Miller-Ricci, M & Rumble, M 2012, 'Defining twenty-first century skills' in P Griffin, B McGaw & ECare (eds), *Assessment and Teaching of 21st Century Skills*, p. 36, Springer, London.

Douglas, R, Klentschy, MP, Worth, K & Binder, W 2006, *Linking Science and Literacy in the K-8 Classroom*, National Science Teachers Association, Arlington, VA.

Feynman, R 1964, *The Character of Physical Law*, Cornell University, Ithaca, NY.

Giancoli, D 2008, *Physics Principles with Applications*, 6th edn, University of California, Berkeley.

Hackling, M 2005, Working Scientifically*: Implementing and assessing open investigation work in science*, Western Australia Department of Education and Training.

Harlen, W 2013, *Assessment and Inquiry-based Science Education: Issues in policy and practice*, Global Network of Science Academies Science Education Programme, Trieste, Italy.

Krajcik, J, Blumenfeld, P, Marx, R & Soloway, E 2000, 'Instructional, curricular, and technological supports for inquiry in science classrooms', in J Minstrell, & E van Zee (eds), *Inquiring into Inquiry Learning and Teaching in Science*, American Association for the Advancement of Science, pp. 283–315, Washington, DC, www.aaas.org/programs/education/about_ehr/pubs/inquiry.shtml.

Krajcik, J & Southerland, J 2010, 'Supporting students in developing literacy in science', *Science*, vol. 328, pp. 456–459, https://doi.org/10.1126/science.1182593.

Macquarie 1981, *Macquarie Concise Dictionary*, 5th edition, Pan Macmillan Australia.

Marzano, RJ & Kendall, JS 2007, *The New Taxonomy of Educational Objectives*, 2nd edn, Corwin Press, USA.

——2008, *Designing and Assessing Educational Objectives: Applying the new taxonomy*, Corwin Press, USA.

Moore, D 2009, 'Science through literacy', *Best Practices in Science Education*, National Geographic, Hampton-Brown, http://ngl.cengage.com/assets/downloads/ngsci_pro0000000028/am_moore_sci_lit_sc122-0459a.pdf.

Queensland Government 2006*, Education (General Provisions)* Act 2006, https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-2006-039

——n.d., *Policy and Procedure Register*, http://ppr.det.qld.gov.au/Pages/default.aspx.

——2011, *Work Health and Safety Act* 2011, https://www.legislation.gov.au/Details/C2016C00887

Saul, EW (ed.) 2004, *Crossing Borders in Literacy and Science Instruction: Perspectives on theory and practice*, International Reading Association, Newark, DE.

Taylor, J 1982, *An Introduction to Error Analysis: The study of uncertainties in physical measurements*, 2nd edn, University Science Books, CA.

Tipler, P & Mosca, G 2003, *Physics for Scientists and Engineers*, 5th edn, WH Freeman, New York.

Tytler, R 2007, *Re-imagining Science Education: Engaging students in science for Australia's future*, ACER Press, Camberwell, Vic.

Yore, L, Bisanz, G & Hand, B 2003, 'Examining the literacy component of science literacy: 25 years of language arts and science research', *International Journal of Science Education*, vol. 25, no. 6, pp. 689–725, http://dx.doi.org/10.1080/09500690305018.

8 Version history

<table>
<tr><th>Version</th><th>Date of change</th><th>Update</th></tr>
<tr><td rowspan="7">1.1</td><td rowspan="7">December 2017</td><td>Editorial changes</td></tr>
<tr><td>Syllabus objective 2: Amendment to explanatory paragraph</td></tr>
<tr><td>IA1: Data test
• Minor amendments to Assessment objectives 2,3 & 4
• Percentage of marks modified
– objective 3 — 40% changed to 30%
– objective 4 — 30% changed to 40%
• Condition amendment (Length) — 400 words changed to ‘up to 500 words’</td></tr>
<tr><td>IA2: Student experiment
• Minor amendment to Assessment objective 5</td></tr>
<tr><td>IA3: Research investigation
• Minor amendments to Assessment objectives 5 & 6</td></tr>
<tr><td>Amendments to ISMGs to reflect modifications to objectives</td></tr>
<tr><td>Glossary update</td></tr>
<tr><td rowspan="6">1.2</td><td rowspan="6">June 2018</td><td>Editorial changes</td></tr>
<tr><td>IA1: Data test
• Minor amendments to Assessment objective 2
• Minor amendments to description and conditions
• Addition of information about cognition and nature of response for each objective</td></tr>
<tr><td>IA2: Student experiment
• Minor editorial changes to ISMG</td></tr>
<tr><td>IA3: Research investigation
• Minor editorial changes to ISMG</td></tr>
<tr><td>EA: Examination
• Minor amendments to Assessment objectives 3 and 4
• Minor amendments to description and conditions</td></tr>
<tr><td>Glossary update</td></tr>
<tr><td>1.3</td><td>July 2022</td><td>Amendments to Unit 1 and Unit 2 Assessment guidance</td></tr>
</table>

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Physics General Senior Syllabus 2019

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