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Stage 6

Syllabus

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Contents

1 The Higher School Certificate Program of Study 5
2 Rationale for Physics in the Stage 6 Curriculum 6
3 Continuum of Learning for Physics Stage 6 Students 7
4 Aim 8
5 Objectives 8
6 Course Structure 9
6.1 Preliminary Course 9
6.2 HSC Course 10
6.3 Overview 11
6.4 Other Considerations 15
7 Objectives and Outcomes 16
7.1 Table of Objectives and Outcomes 16
7.2 Key Competencies 18
8 Content: Physics Stage 6 Preliminary Course 19
8.1 Physics Skills 19
8.2 The World Communicates 22
8.3 Electrical Energy in the Home 29
8.4 Moving About 35
8.5 The Cosmic Engine 41
9 Content: Physics Stage 6 HSC Course 46
9.1 Physics Skills 46
9.2 Space 49
9.3 Motors and Generators 54
9.4 From Ideas to Implementation 58
9.5 Option — Geophysics 63
9.6 Option — Medical Physics 67
9.7 Option — Astrophysics 71
9.8 Option — From Quanta to Quarks 75
9.9 Option — The Age of Silicon 79
10 Course Requirements 83
11 Post-school Opportunities 84
12 Assessment and Reporting 85
12.1 Requirements and Advice 85
12.2 Internal Assessment 86
12.3 External Examination 86
12.4 Board Requirements for the Internal Assessment Mark in Board Developed Courses 87
12.5 Assessment Components, Weightings and Tasks 88
12.6 HSC External Examination Specifications 90
12.7 Summary of Internal and External Assessment 91
12.8 Reporting Student Performance Against Standards 92

1 The Higher School Certificate Program of Study

The purpose of the Higher School Certificate program of study is to:

- provide a curriculum structure which encourages students to complete secondary education;

- foster the intellectual, social and moral development of students, in particular developing their:
  - knowledge, skills, understanding and attitudes in the fields of study they choose
  - capacity to manage their own learning
  - desire to continue learning in formal or informal settings after school
  - capacity to work together with others
  - respect for the cultural diversity of Australian society;

- provide a flexible structure within which students can prepare for:
  - further education and training
  - employment
  - full and active participation as citizens;

- provide formal assessment and certification of students' achievements;

- provide a context within which schools also have the opportunity to foster students' physical and spiritual development.

2 Rationale for Physics in the Stage 6 Curriculum

Physics in Science Stage 6 provides students with a contemporary and coherent understanding of energy, matter, and their interrelationships. It focuses on investigating natural phenomena and then applying patterns, models (including mathematical ones), principles, theories and laws to explain the physical behaviour of the universe. It uses an understanding of simple systems (single particles and pairs of particles) to make predictions about a range of objects from sub-atomic particles to the entire universe and aims to reveal the simplicity underlying complexity.

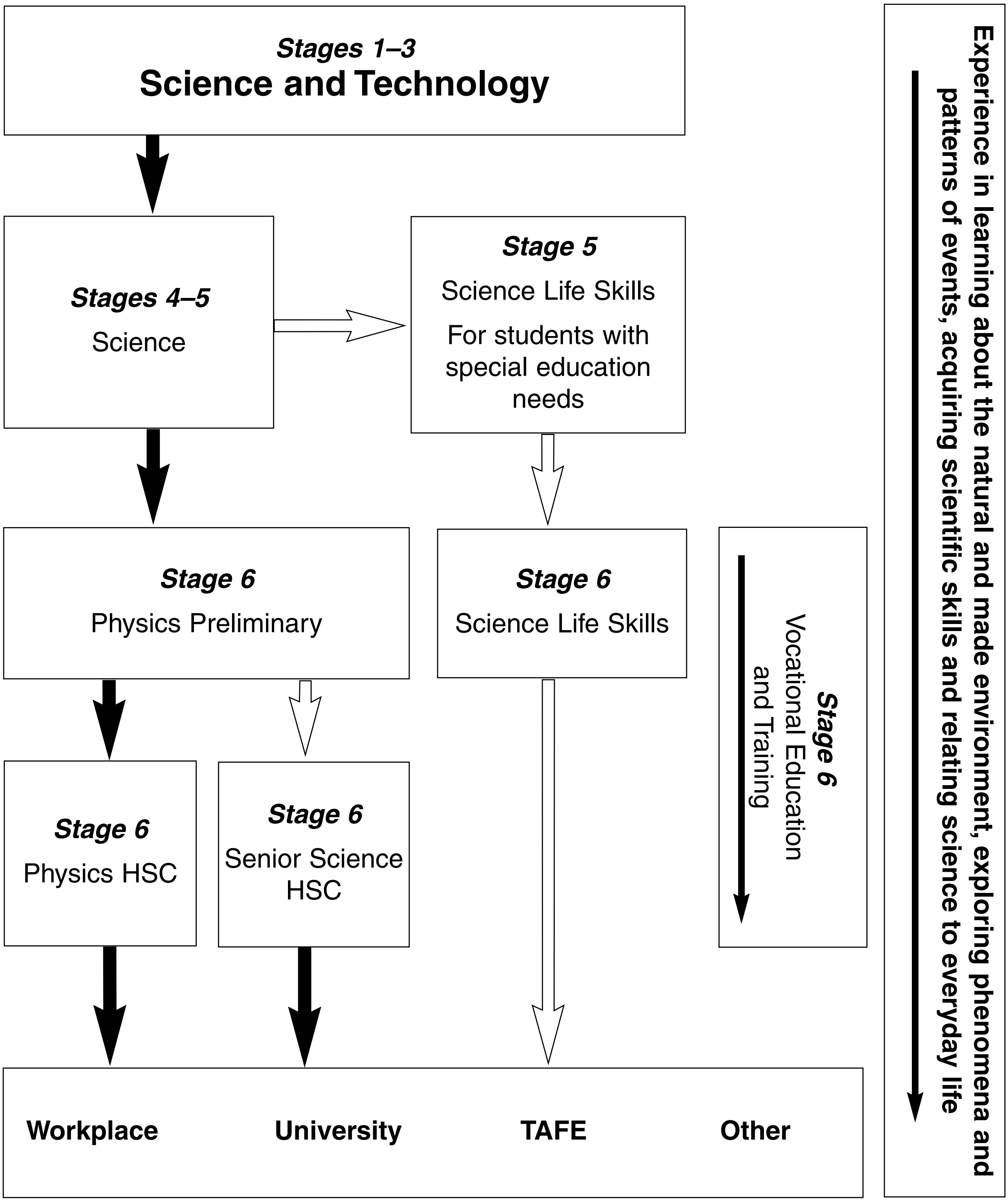
The study of physics relies on the understanding and application of a small number of basic laws and principles that govern the microscopic and macroscopic worlds. The study of physics provides students with an understanding of systems that is the basis of the development of technological applications. The interplay between concepts and technological and societal impacts is embodied in the history and philosophy of science and forms a continuum relating our past to our future.

Physics Stage 6 draws upon and builds on the knowledge and understanding, skills and values and attitudes developed in Science Stages 4–5. It further develops students' understanding of science as a continually developing body of knowledge, the interdisciplinary nature of science, the role of experiment in deciding between competing theories, the provisional nature of scientific explanations, the complex relationship between evidence and ideas and the impact of science on society.

The study of physics involves the students working individually and with others in active, practical, field and interactive media experiences that are related to the theoretical concepts considered in the course. It is expected that students studying Physics Stage 6 will apply investigative and problem-solving skills, effectively communicate the theoretical concepts considered in the course and appreciate the contribution that a study of physics makes to our understanding of the world.

The Physics Stage 6 course is designed for those students who have a substantial achievement level based on the Science Stages 4–5 course performance descriptors. The subject matter of the Physics course recognises the different needs and interests of students by providing a structure that builds upon the foundations laid in Stage 5 yet recognises that students entering Stage 6 have a wide range of abilities, circumstances and expectations.

3 Continuum of Learning for Physics Stage 6 Students



4 Aim

Physics Stage 6 aims to provide learning experiences through which students will:

- acquire knowledge and understanding about fundamental concepts related to natural phenomena and their causes, the historical development of these concepts and their application to personal, social, economic, technological and environmental situations
- progress from the consideration of specific data and knowledge to the understanding of models and concepts and the explanation of generalised physics terms; from the collection and organisation of information to problem-solving; and from the use of simple communication skills to those that are more sophisticated
- develop positive attitudes towards the study of natural phenomena and their causes and opinions held by others, recognising the importance of evidence and the use of critical evaluation of differing scientific opinions related to various aspects of physics.

5 Objectives

Students will develop knowledge and understanding of:

1. the history of physics
2. the nature and practice of physics
3. applications and uses of physics
4. the implications of physics for society and the environment
5. current issues, research and developments in physics
6. kinematics and dynamics
7. energy
8. waves
9. fields
10. matter.

Students will develop further skills in:

11. planning investigations
12. conducting investigations
13. communicating information and understanding
14. developing scientific thinking and problem-solving techniques
15. working individually and in teams.

Students will develop positive values about and attitudes towards:

16. themselves, others, learning as a lifelong process, physics and the environment.

6 Course Structure

This *Physics Stage 6 Syllabus* has a Preliminary course and an HSC course. The Preliminary and HSC courses are organised into a number of modules. The Preliminary modules consist of core content that will be covered in 120 indicative hours.

The HSC course consists of core and options organised into a number of modules. The core content covers 90 indicative hours with options covering 30 indicative hours. Students are required to complete one of the options.

Practical experiences are an essential component of both the Preliminary and HSC courses. Students will complete 80 indicative hours of practical/field work during the Preliminary and HSC courses with no less than 35 indicative hours of practical experiences in the HSC course. Practical experiences must include at least one open-ended investigation integrating the knowledge and understanding, and skills outcomes in both the Preliminary and HSC courses.

Practical experiences should emphasise hands-on activities, including:
- undertaking laboratory experiments, including the use of appropriate computer based and digital technologies
- fieldwork
- research using a wide range of sources, including print material, the Internet and digital technologies
- the use of computer simulations for modelling or manipulating data
- using and reorganising secondary data
- extracting and reorganising information in the form of flow charts, tables, graphs, diagrams, prose and keys
- the use of animation, video and film resources that can be used to capture/obtain information not available in other forms.

6.1 Preliminary Course

120 indicative hours

The Preliminary course incorporates the study of:
- The World Communicates (30 indicative hours)
- Electrical Energy in the Home (30 indicative hours)
- Moving About (30 indicative hours)
- The Cosmic Engine (30 indicative hours)

6.2 HSC Course

120 indicative hours

The HSC course builds upon the Preliminary course. The Preliminary course content is a prerequisite for the HSC course.

The HSC course incorporates the study of:

a) the core, which includes:

- Space (30 indicative hours)
- Motors and Generators (30 indicative hours)
- From Ideas to Implementation (30 indicative hours)

b) options, which constitute 30 indicative hours and include any one of the following:

- Geophysics
- Medical Physics
- Astrophysics
- From Quanta to Quarks
- The Age of Silicon

6.3 Overview

The following diagram summarises the relationship between the various elements of the course:

Aim
states the overall purpose of the syllabus

↓

Objectives
define in broad terms, the knowledge and understanding, skills, and values and attitudes

Outcomes
define the intended results of teaching

↓

Content of each module

Contexts
to increase motivation, conceptual meaning, literacy or confidence

Prescribed Focus Areas
identify emphases that are applied to what is being learned

Domain
contains knowledge and understanding, skills, and values and attitudes to be learned

set within a background of ongoing assessment aimed at assissting students to learn

↓

An independent learner
creative, responsible, scientifically literate, confident, ready to take their place as a member of society

Context

Contexts are frameworks devised to assist students to make meaning of the Prescribed Focus Areas and Domain. Contexts are culturally bound and therefore communicate meanings that are culturally shaped or defined. Contexts draw on the framework of society in all aspects of everyday life. The contexts for each module encourage students to recognise and use their current understanding to further develop and apply more specialised scientific understanding and knowledge.

Prescribed Focus Areas

The Prescribed Focus Areas are different curriculum emphases or purposes designed to increase students' understanding of physics as an ever-developing body of knowledge, the provisional nature of scientific explanations in physics, the complex relationship between evidence and ideas in physics and the impact of physics on society.

The following Prescribed Focus Areas are developed in this syllabus:

History of physics

Knowledge of the historical background of physics is important to adequately understand natural phenomena and explain the applications of those phenomena in current technologies. Students should develop knowledge of:

- the developmental nature of our understanding of energy, matter and their interrelationships
- the part that an understanding of energy, matter and their interrelationships plays in shaping society
- how our understanding of energy, matter and their interrelationships is influenced by society.

Nature and practice of physics

A study of physics should enable students to participate in scientific activities and develop knowledge of the practice of physics. Students should develop knowledge of the provisional nature of physical explanations and the complex relationship between:

- existing physical views and the evidence supporting these
- the process and methods of exploring, generating, testing and relating ideas
- the stimulation provided by technological advances and constraints imposed on understanding in physics by the limitations of current technology that necessitates the development of the required technology and technological advances.

Applications and uses of physics

Setting the study of physics into broader contexts allows students to deal with real problems and applications. The study of physics should increase students' knowledge of:

- the relevance, usefulness and applicability of laws and principles related to physics

- how increases in our understanding in physics have led to the development of useful technologies and systems
- the contributions physics has made to society, with particular emphasis on Australian achievements.

Implications of physics for society and the environment

Physics has an impact on our society and the environment, and students need to develop knowledge of the importance of positive values and practices in relation to these. The study of physics should enable students to develop:

- understanding about the impact and role of physics in society and the environment
- skills in decision-making about issues concerning physics, society and the environment.

Current issues, research and developments in physics

Issues and developments related to physics are more readily known and more information is available to students than ever before. The syllabus should develop students' knowledge of:

- areas currently being researched in physics
- career opportunities in physics and related fields
- events reported in the media which require an understanding of some aspect of physics.

Domain

Knowledge and understanding

As one of the major disciplines of science, the Physics Stage 6 course presents a particular way of thinking about the world. It encourages students to use inference, deductive reasoning and creativity. It presumes that the interrelationships within and between matter and energy in the universe occur in consistent patterns that can be understood through careful, systematic study.

The course extends the study developed in the Science Stages 4–5 course, particularly in relation to students' knowledge and understanding of the law of conservation of energy, Newton's Laws, the wave model, particle theory of matter, atomic theory, types of energy, types of force, technology and resources.

This course will build upon this fundamental knowledge to increase students' conceptual understanding of systems involving energy, force and motion as well as interactions between these systems and the living and non-living world. The course will assume that students have an elementary knowledge and understanding of energy, motion, electricity and forces as developed in the Science Stages 4–5 course.

Skills

The Physics Stage 6 course involves the further development of the skills students have developed in the Science Stages 4–5 course through a range of practical experiences in both the Preliminary and HSC courses.

Practical experiences are an essential component of both the Preliminary and HSC courses. Students will complete **80 indicative hours of practical/field work across both the Preliminary and HSC courses** with no less than 35 indicative hours of practical experiences in the HSC course. Practical experiences have been designed to utilise and further develop students' expertise in each of the following skill areas:

- **planning investigations**

  This involves increasing students' skills in planning and organising activities, effectively using time and resources, selecting appropriate techniques, materials, specimens and equipment to complete activities, establishing priorities between tasks and identifying ways of reducing risks when using laboratory and field equipment.
- **conducting investigations**

  This involves increasing students' skills in locating and gathering information for a planned investigation. It includes increasing students' skills in performing first-hand investigations, gathering first-hand data and accessing and collecting information relevant to physics from secondary sources using a variety of technologies.
- **communicating information and understanding**

  This involves increasing students' skills in processing and presenting information. It includes increasing students' skills in speaking, writing and using nonverbal communication, such as diagrams, graphs and symbols to convey physical information and understandings. Throughout the course, students become increasingly efficient and competent in the use of both technical terminology and the form and style required for written and oral communication in physics.
- **developing scientific thinking and problem-solving techniques**

  This involves further increasing students' skills in clarifying issues and problems relevant to physics, framing a possible problem-solving process, developing creative solutions, anticipating issues that may arise, devising appropriate strategies to deal with those issues and working through the issues in a logical and coherent way.
- **working individually and in teams**

  This involves further increasing students' skills in identifying a collective goal, defining and allocating roles and assuming an increasing variety of roles in working as an effective member of a team within the agreed time frame to achieve the goal. Throughout the course, students will be provided with further opportunities to improve their ability to communicate and relate effectively with each other in a team.

Values and attitudes

By reflecting about past, present and future involvement of physics with society, students are encouraged to develop positive values and informed critical attitudes. These include a responsible regard for both the living and non-living components of the environment, ethical behaviour, a desire for critical evaluation of the consequences of the applications of physics and recognising their responsibility to conserve, protect and maintain the quality of all environments for future generations.

Students are encouraged to develop attitudes on which scientific investigations depend such as curiosity, honesty, flexibility, persistence, critical thinking, willingness to suspend judgement, tolerance of uncertainty and an acceptance of the provisional status of scientific knowledge. Students need to balance these with commitment, tenacity, a willingness to take risks, make informed judgements and at times, inflexibility. As well as knowing something about physics, students also need to value and appreciate physics if they are to become scientifically literate persons.

6.4 Other Considerations

Safety Issues

Schools have a legal obligation in relation to safety. Teachers will need to ensure that they comply with the *Occupational Health and Safety Act 1983* (NSW), the *Dangerous Goods Act 1975* (NSW), the Dangerous Goods Regulation 1978 (NSW) and the Hazardous Substances Regulation 1996 (NSW), as well as system and school requirements in relation to safety when implementing their programs.

Animal Welfare Act

Schools have a legal responsibility in relation to the welfare of animals. All practical activities involving animals must comply with the *Animal Welfare Act 1985* (NSW) as described in the *Animals in Schools: Animal Welfare Guidelines for Teachers* produced on behalf of the Schools Animal Care and Ethics Committee (SACEC) by the NSW Department of the Education and Training.

7 Objectives and Outcomes

7.1 Table of Objectives and Outcomes

	Objectives		Preliminary Course Outcomes		HSC Course Outcomes	
Prescribed Focus Area	Students will develop knowledge and understanding of:		A student:		A student:	
	1	the history of physics	P1	outlines the historical development of major principles, concepts and ideas in physics	H1	evaluates how major advances in scientific understanding and technology have changed the direction or nature of scientific thinking
	2	the nature and practice of physics	P2	applies the processes that are used to test and validate models, theories and laws of science with particular emphasis on first-hand investigations in physics	H2	analyses the ways in which models, theories and laws in physics have been tested and validated
	3	applications and uses of physics	P3	assesses the impact of particular technological advances on understanding in physics	H3	assesses the impact of particular advances in physics on the development of technologies
	4	implications of physics for society and the environment	P4	describes applications of physics which affect society or the environment	H4	assesses the impact of applications of physics on society and the environment
	5	current issues, research and developments in physics	P5	describes the scientific principles employed in particular areas of physics research	H5	identifies possible future directions of physics research
Domain: Knowledge	Students will develop knowledge and understanding of:		A student:		A student:	
	6	kinematics and dynamics	P6	describes the forces acting on an object which cause changes in its motion	H6	explains events in terms of Newton's Laws, Law of Conservation of Momentum and relativity
	7	energy	P7	describes the effects of energy transfers and energy transformations	H7	explains the effect of energy transfers and transformation
	8	waves	P8	explains wave motions in terms of energy sources and the oscillations produced	H8	analyses wave interactions and explains the effects of those interactions
	9	fields	P9	describes the relationship between force and potential energy in fields	H9	explains the effects of electric, magnetic and gravitational fields
	10	matter	P10	describes theories and models in relation to the origins of matter and relates these to the forces involved	H10	describes the nature of electromagnetic radiation and matter in terms of the particles

	Objectives	Preliminary Course Outcomes	HSC Course Outcomes
Domain: Skills	Students will develop skills in:	A student:	A student:
	11 planning investigations	P11 identifies and implements improvements to investigation plans	H11 justifies the appropriateness of a particular investigation plan
	12 conducting investigations	P12 discusses the validity and reliability of data gathered from first-hand investigations and secondary sources	H12 evaluates ways in which accuracy and reliability could be improved in investigations
	13 communicating information and understanding	P13 identifies appropriate terminology and reporting styles to communicate information and understanding in physics	H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding
	14 developing scientific thinking and problem-solving techniques	P14 draws valid conclusions from gathered data and information	H14 assesses the validity of conclusions drawn from gathered data and information
	15 working individually and in teams	P15 implements strategies to work effectively as an individual or as a member of a team	H15 explains why an investigation is best undertaken individually or by a team
Domain: Values and Attitudes	Students will develop positive values about and attitudes towards:	A student:	A student:
	16 themselves, others, learning as a lifelong process, physics and the environment	P16 demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science	H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science

7.2 Key Competencies

Physics Stage 6 provides the context within which to develop general competencies considered essential for the acquisition of effective, higher-order thinking skills necessary for further education, work and everyday life.

Key competencies are embedded in the *Physics Stage 6 Syllabus* to enhance student learning and are explicit in the objectives and outcomes of the syllabus. The key competencies of ***collecting, analysing and organising information*** and ***communicating ideas and information*** reflect core processes of scientific inquiry and the skills identified in the syllabus assist students to continue to develop their expertise in these areas.

Students work as individuals and as members of groups to conduct investigations and, through this, the key competencies, ***planning and organising activities*** and ***working with others and in teams***, are developed. During investigations, students use appropriate information technologies and so develop the key competency of ***using technology***. The exploration of issues and investigation of problems contributes towards students' development of the key competency ***solving problems***. Finally, when students analyse statistical evidence, apply mathematical concepts to assist analysis of data and information and construct tables and graphs, they are developing the key competency ***using mathematical ideas and techniques***.

8 Content: Physics Stage 6 Preliminary Course

8.1 Physics Skills

During the Preliminary course, it is expected that students will further develop skills in planning and conducting investigations, communicating information and understanding, scientific thinking and problem-solving and working individually and in teams. Each module specifies content through which skill outcomes can be achieved. Teachers should develop activities based on that content to provide students with opportunities to develop the full range of skills.

Preliminary Course Outcomes	Content
A student: P11. identifies and implements improvements to investigation plans	*Students:* **11.1 identify data sources to:** a) analyse complex problems to determine appropriate ways in which each aspect may be researched b) determine the type of data that needs to be collected and explain the qualitative or quantitative analysis that will be required for this data to be useful c) identify the orders of magnitude that will be appropriate and the uncertainty that may be present in the measurement of data d) identify and use correct units for data that will be collected e) recommend the use of an appropriate technology or strategy for data collection or information gathering that will assist efficient future analysis
	11.2 plan first-hand investigations to: a) demonstrate the use of the terms ‘dependent’ and ‘independent’ to describe variables involved in the investigation b) identify variables that need to be kept constant, develop strategies to ensure that these variables are kept constant, and demonstrate the use of a control c) design investigations that allow valid and reliable data and information to be collected d) describe and trial procedures to undertake investigations and explain why a procedure, a sequence of procedures or the repetition of procedures is appropriate e) predict possible issues that may arise during the course of an investigation and identify strategies to address these issues if necessary
	11.3 choose equipment or resources by: a) identifying and/or setting up the most appropriate equipment or combination of equipment needed to undertake the investigation b) carrying out a risk assessment of intended experimental procedures and identifying and addressing potential hazards c) identifying technology that could be used during investigations and determining its suitability and effectiveness for its potential role in the procedure or investigation d) recognising the difference between destructive and non-destructive testing of material and analysing potentially different results from these two procedures

Preliminary Course Outcomes	Content
A student: P12. discusses the validity and reliability of data gathered from first-hand investigations and secondary sources	*Students:* **12.1 perform first-hand investigations by:** a) carrying out the planned procedure, recognising where and when modifications are needed and analysing the effect of these adjustments b) efficiently undertaking the planned procedure to minimise hazards and wastage of resources c) disposing carefully and safely of any waste materials produced during the investigation d) identifying and using safe work practices during investigations
	12.2 gather first-hand information by: a) using appropriate data collection techniques, employing appropriate technologies, including data loggers and sensors b) measuring, observing and recording results in accessible and recognisable forms, carrying out repeat trials as appropriate
	12.3 gather information from secondary sources by: a) accessing information from a range of resources, including popular scientific journals, digital technologies and the Internet b) practising efficient data collection techniques to identify useful information in secondary sources c) extracting information from numerical data in graphs and tables as well as from written and spoken material in all its forms d) summarising and collating information from a range of resources e) identifying practising male and female Australian scientists, the areas in which they are currently working and information about their research
	12.4 process information to: a) assess the accuracy of any measurements and calculations and the relative importance of the data and information gathered b) identify and apply appropriate mathematical formulae and concepts c) best illustrate trends and patterns by selecting and using appropriate methods, including computer assisted analysis d) evaluate the validity of first-hand and secondary information and data in relation to the area of investigation e) assess the reliability of first-hand and secondary information and data by considering information from various sources f) assess the accuracy of scientific information presented in mass media by comparison with similar information presented in scientific journals

Preliminary Course Outcomes	Content
A student: P13. identifies appropriate terminology and reporting styles to communicate information and understanding in physics	*Students:* **13.1 present information by:** a) selecting and using appropriate text types or combinations thereof, for oral and written presentations b) selecting and using appropriate media to present data and information c) selecting and using appropriate methods to acknowledge sources of information d) using symbols and formulae to express relationships and using appropriate units for physical quantities e) using a variety of pictorial representations to show relationships and present information clearly and succinctly f) selecting and drawing appropriate graphs to convey information and relationships clearly and accurately g) identifying situations where use of a curve of best fit is appropriate to present graphical information
P14. draws valid conclusions from gathered data and information	**14.1 analyse information to:** a) identify trends, patterns and relationships as well as contradictions in data and information b) justify inferences and conclusions c) identify and explain how data supports or refutes an hypothesis, a prediction or a proposed solution to a problem d) predict outcomes and generate plausible explanations related to the observations e) make and justify generalisations f) use models, including mathematical ones, to explain phenomena and/or make predictions g) use cause and effect relationships to explain phenomena h) identify examples of the interconnectedness of ideas or scientific principles
	14.2 solve problems by: a) identifying and explaining the nature of a problem b) describing and selecting from different strategies, those which could be used to solve a problem c) using identified strategies to develop a range of possible solutions to a particular problem d) evaluating the appropriateness of different strategies for solving an identified problem
	14.3 use available evidence to: a) design and produce creative solutions to problems b) propose ideas that demonstrate coherence and logical progression and include correct use of scientific principles and ideas c) apply critical thinking in the consideration of predictions, hypotheses and the results of investigations d) formulate cause and effect relationships

8.2 The World Communicates

Contextual Outline

Humans are social animals and have successfully communicated through the spoken word, and then, as the use of written codes developed, through increasingly sophisticated graphic symbols. The use of a hard copy medium to transfer information in coded form meant that communication was able to cross greater spatial and time barriers. A messenger was required to carry the information in hard copy form and this messenger could have been a vehicle or person. There was, however, still a time limit and several days were needed to get hard copy information from one side of the world to the other.

The discovery of electricity and then the electromagnetic spectrum has led to the rapid increase in the number of communication devices throughout the twentieth century. The messenger carrying the information is no longer a vehicle or person — rather, an increasing range of energy waves is used to transfer the message. The delay in relaying signals around the world is determined only by the speed of the wave, and the speed and efficiency of the coding and decoding devices at the departure and arrival points of the message. The time between sending and receiving messages through telecommunications networks is measured in fractions of a second allowing almost instantaneous delivery of messages, in spoken and coded forms, around the world.

Assumed Knowledge

Domain: knowledge and understanding:

Refer to the *Science Stages 4–5 Syllabus* for the following:

5.6.1a identify waves as carriers of energy

5.6.1b qualitatively describe features of waves including frequency, wavelength and speed

5.6.1c give examples of different types of radiation that make up the electromagnetic spectrum and identify some of their uses

5.6.4a distinguish between the absorption, reflection, refraction and scattering of light and identify everyday situations where each occurs

5.9.1b identify that some types of electromagnetic radiation are used to provide information about the universe

5.12c describe some everyday uses and effects of electromagnetic radiation, including applications in communication technology.

Outcomes

The main course outcomes to which this module contributes are:

A student:

P2	applies the processes that are used to test and validate models, theories and laws of science with particular emphasis on first-hand investigations in physics
P3	assesses the impact of particular technological advances on understanding in physics
P5	describes the scientific principles employed in particular areas of physics research
P7	describes the effects of energy transfers and energy transformations
P8	explains wave motions in terms of energy sources and the oscillations produced
P11	identifies and implements improvements to investigation plans
P12	discusses the validity and reliability of data gathered from first-hand investigations and secondary sources
P13	identifies appropriate terminology and reporting styles to communicate information and understanding in physics
P14	draws valid conclusions from gathered data and information
P15	implements strategies to work effectively as an individual or as a member of a team
P16	demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Current technologies associated with information transfer may use waves of one form or another	• recall that waves are carriers of energy • describe the energy transformations required in one of the following: – fixed telephone – mobile telephone – fax/modem – radio and television – information storage systems • describe waves as a transfer of energy disturbance that may occur in one, two or three dimensions, depending on the nature of the wave and the medium • recall that the features of a wave include frequency, wavelength and speed • explain that mechanical waves require a medium for propagation while electromagnetic waves do not • define and apply the following terms to the wave model: 'medium', 'displacement', 'amplitude', 'period', 'compression', 'rarefaction', 'crest', 'trough', 'transverse waves', 'longitudinal waves', 'frequency', 'wavelength', 'velocity' • describe the relationship between particle motion and the direction of energy propagation in transverse and longitudinal waves • quantify the relationship between velocity, frequency and wavelength for a wave: $v = f\lambda$	• perform a first-hand investigation to observe and gather information about the transmission of waves in: – slinky springs – water waves – ropes or use appropriate computer simulations • present diagrammatic information showing the troughs and crests of transverse waves and calculate the wavelength and amplitude • present diagrammatic information about transverse and longitudinal waves, showing wavefronts and the propagation direction • perform a first-hand investigation to gather information about the frequency, amplitude and velocity of waves using an oscilloscope or electronic data-logging equipment • present and analyse information from displacement-time graphs for transverse wave motion • plan, choose equipment for and perform a first-hand investigation to gather information to identify the relationship between frequency and wavelength of a wave travelling at a constant velocity • solve problems and analyse information by applying the mathematical model of $v = f\lambda$ to a range of situations

	Students learn to:	*Students:*
2. Sound waves can be used to illustrate many of the properties of waves that are utilised in communication technologies	• identify that sound waves are vibrations or oscillations of particles in a medium • discuss the effect of density of the medium on the transmission speed of sound waves • relate compressions and rarefactions of sound waves to the crests and troughs of transverse waves • explain qualitatively that pitch is related to frequency and volume to amplitude of sound waves • explain an echo as a reflection of a sound wave • describe the effect of different materials on the reflection and absorption of sound • describe the transfer of energy involved in the absorption of sound • describe the principle of superposition in standing waves and compare the resulting waves to the original waves in sound	• perform a first-hand investigation and gather information to analyse sound wave forms from a variety of sources using the Cathode Ray Oscilloscope (CRO) or computer technology • identify data sources, plan, choose equipment or resources for, and perform a first-hand investigation to model the effect of different materials on the reflection and absorption of sound • perform a first-hand investigation, gather, process and present information using a CRO or computer to demonstrate the principle of superposition for two waves travelling in the same medium • present graphical information, solve problems and analyse information involving superposition of sound waves

3. Recent technological developments have allowed greater use of waves in the electromagnetic spectrum that do not require a medium for propagation

Students learn to:

- recall that different types of radiation make up the electromagnetic spectrum
- describe electromagnetic waves in terms of their speed in space and their lack of requirement of a medium for propagation
- recall that electromagnetic radiation has some everyday uses and effects, including applications in communication technology
- identify some methods of detection for a number of wave bands from the electromagnetic spectrum
- explain that the penetrating power of electromagnetic waves is related to differences in frequency or wavelength
- explain that the relationship between the intensity of electromagnetic radiation and distance from a source (for a large distance) is an example of the inverse square law
  ($I \propto \frac{1}{d^2}$)
- outline how the modulation of amplitude or frequency of visible light, microwaves and/or radio waves can be used to transmit information
- discuss limitations of the use of electromagnetic waves for communication purposes

Students:

- identify data sources and gather information from secondary sources to chart the depth of penetration in the atmosphere of electromagnetic spectrum waves and identify the wavelengths filtered out by the atmosphere, especially UV, X-rays and gamma rays
- plan, choose equipment or resources for and perform a first-hand investigation and gather information to model the inverse square law for light intensity and distance from the source
- solve problems, analyse information and use available evidence to identify the waves involved in the transfer of energy that occur during the use of one of the following:
  – mobile phone
  – television
  – radar

4. Many communication technologies use applications of reflection and refraction of electromagnetic waves

Students learn to:

- discuss the law of reflection and explain the effect of reflection on waves from a plane surface
- apply qualitatively, the law of reflection to reflection of waves from a plane surface
- describe ways in which applications of reflection of light, radio waves and microwaves have assisted in information transfer
- describe one application of reflection for each of the following:
  - plane surfaces
  - concave surfaces
  - convex surfaces
  - radio waves and their reflection by the ionosphere
- describe refraction in terms of the bending of the wavefront passing from one medium to another
- explain that refraction is related to the different velocities exhibited by a wave in two media
- define refractive index in terms of changes in the velocity of a wave in passing from one medium to another
- define and discuss the application of Snell's Law:

  $$\frac{v_1}{v_2} = \frac{\sin i}{\sin r}$$
- identify the conditions necessary for total internal reflection and determine critical angle
- outline how refraction and/or total internal reflection are used in technologies such as lenses or optical fibres

Students:

- perform first-hand investigations and gather information to observe the path of light rays and construct diagrams indicating both the direction of travel of the light rays and a wave front
- gather and analyse information to assess the impact of the development of lenses on the understanding of the nature of light
- present information using ray diagrams to show the path of waves reflected from:
  - plane surfaces
  - concave surfaces
  - convex surface
  - the ionosphere
- perform an investigation and gather information to graph the angle of incidence and refraction for light encountering a medium change showing the relationship between these angles
- perform a first-hand investigation and gather information to measure the refractive index of glass or perspex, compare the result with a published value and propose explanations for any differences
- solve problems and analyse information using Snell's Law

	Students learn to:	*Students:*
5. Other properties of electromagnetic waves have potential for future communication technologies and data storage technologies	• identify types of communication data that are stored or transmitted in digital form • discuss the developments in technology that allowed the production of communication technologies, such as CD technology and Global Positioning Systems	• identify data sources, gather, process and present information from secondary sources to identify areas of current research and use the available evidence to discuss some of the underlying physical principles used in one application of physics related to waves, such as: – Global Positioning System – petrological microscope – CD technology, including differences between CD and DVD – the Internet (digital process)

8.3 Electrical Energy in the Home

Contextual Outline

Modern society is geared to using electricity. Electricity has characteristics that have made it uniquely appropriate for powering a highly technological society. There are many energy sources that can be readily converted into electricity. In Australia, most power plants burn a fuel, such as coal, or use the energy of falling water to generate electricity on a large-scale. Electricity is also relatively easy to distribute. Electricity authorities use high-voltage transmission lines and transformers to distribute electricity to homes and industries around each state. Voltages can be as high as 5×10^5 volts from power stations, by the time this reaches homes, the electricity has been transformed to 240 volts. While it is relatively economical to generate electric power at a steady rate, there are both financial and environmental issues that should be considered when assessing the long-term impact of supplying commercial and household power.

As electricity became increasingly used as the main power supply in homes and electrical appliances became an integral part of daily life for many Australians, the dangers associated with electricity have become more prominent. Voltages as low as 20 volts can be dangerous to the human body depending on the health of the person and length of time of contact with the current. Safety devices in household appliances and within the electric circuits in the home can prevent electrical injury or assist in reducing the potential for electric shock.

Assumed Knowledge

Domain: knowledge and understanding:

Refer to the *Science Stages 4–5 Syllabus* for the following:

5.6.3a design, construct and draw circuits containing a number of components
5.6.3b describe voltage, resistance and current using analogies
5.6.3c describe qualitatively, the relationship between voltage, resistance and current
5.6.3d compare advantages and disadvantages of series and parallel circuits

Outcomes

The main course outcomes to which this module contributes are:

A student:

- P1 outlines the historical development of major physics principles, concepts and ideas
- P2 applies the processes that are used to test and validate models, theories and laws of science with particular emphasis on first-hand investigations in physics
- P3 assesses the impact of particular technological advances on understanding in physics
- P7 describes the effects of energy transfers and energy transformations
- P9 describes the relationship between force and potential energy in fields
- P11 identifies and implements improvements to investigation plans
- P12 discusses the validity and reliability of data gathered from first-hand investigations and secondary sources
- P13 identifies appropriate terminology and reporting styles to communicate information and understanding in physics
- P14 draws valid conclusions from gathered data and information
- P15 implements strategies to work effectively as an individual or as a member of a team
- P16 demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Society has become increasingly dependent on electricity over the last 200 years	• discuss how the main sources of domestic energy have changed over time • assess some of the impacts of changes in, and increased access to, sources of power for a community • discuss some of the ways in which electricity can be provided in remote locations	• identify data sources, gather, process and analyse secondary information about the debate that took place between Volta and Galvani about animal and chemical electricity and discuss how it contributed to increased understanding about electricity • identify data sources, gather secondary information, process, analyse, present the information and use the available evidence to show how a type of energy source used by society and access to it has changed

	Students learn to:	*Students:*
2. One of the main advantages of electricity is that is can be moved with comparative ease from one place to another through electric circuits	• describe the behaviour of electrostatic charges and the field associated with them • define the unit of electric charge as the coulomb • describe the electric field as a field of force with a field strength equal to the force per unit charge at that point $E = \frac{F}{q}$ • recall the use of the terms current, voltage, and resistance in electric circuits • define electric current as the rate at which charge flows (coulombs/second or amperes) under the influence of an electric field • identify that current can be either direct with the net flow of charge carriers moving in one direction or alternating with the charge carriers moving backwards and forwards periodically • describe potential difference (voltage) between two points as the change in potential energy per unit charge moving from one point to the other (joules/coulomb or volts) • discuss how potential difference between different points around a circuit varies • describe the difference between conductors and insulators • discuss qualitatively how each of the following affects the movement of electricity through a conductor: – length – cross sectional area – temperature – material	• present diagrammatic information to describe the electric field strength and direction of: – parallel plates – a positive and negative point charge • solve problems and analyse information using $E = \frac{F}{q}$ • perform an investigation to compare current through, and voltage across, AC and DC circuits • plan, choose equipment for and perform a first-hand investigation to gather data and use the available evidence to show the relationship between voltage and current • solve problems and analyse information applying $R = \frac{V}{I}$ • plan, choose equipment for and perform a first-hand investigation to gather data and use the available evidence to show the variations in potential difference between different points around a circuit • gather and process secondary information to identify materials that are commonly used as conductors to provide household electricity

	Students learn to:	*Students:*
3. Series and parallel circuits serve different purposes in households	• recall the terms, series and parallel circuits • discuss the distinction between series and parallel circuits in terms of the flow of current • compare parallel and series circuits in terms of voltage across components and the current through them • explain why ammeters and voltmeters are connected differently in a circuit • explain why there are different circuits for lighting, heating and other appliances in a house	• plan, choose equipment or resources for and perform first-hand investigations to gather data and use available evidence to compare measurements of current and voltage in series and parallel circuits in computer simulations or hands-on equipment • gather, process and analyse first-hand and secondary information to compare the structure of a household circuit for different purposes • plan, choose equipment or resources for process information and perform a first hand investigation to construct model household circuits using electrical components
4. The amount of power is related to the rate at which energy is transformed	• explain that power is related to the rate at which energy is transformed from one form to another • describe the relationship between power, potential difference and current • explain that the total amount of energy used depends on the length of time the current is flowing and can be calculated using: $\text{Energy} = VIt$ • assess the advantages and disadvantages of labelling goods with power rating • explain why a simple scale has been used for energy rating on commercial goods and how these scales relate to potential difference and current	• perform a first-hand investigation, gather information and use available evidence to demonstrate the relationship between current, voltage and power for a model 12V electric heating coil • solve problems and analyse information using $P=VI$ and $\text{Energy} = VIt$ for a variety of situations • analyse information to propose reasons as to why the kilowatt-hour is used to measure domestic electricity consumption rather than the joule • gather, process and analyse secondary information on the use of energy efficiency rating scales and the process used to allocate a rating scale to a commercial product • gather and process first-hand information to estimate the cost of electricity consumed by households and discuss ways in which consumption could be reduced

	Students learn to:	*Students:*
5. Electric currents also produce magnetic fields and these fields are used in different technologies in the home	• describe the behaviour of the magnetic poles when they are brought close together • define the direction of the magnetic field at a point as the direction of force on a very small magnetic pole when placed at that point • describe the magnetic field around single magnetic poles and pairs of magnetic poles • describe the production of a magnetic field by an electric current in a straight current-carrying conductor and describe how the right hand grip rule can determine the direction of current and field lines • compare the nature and generation of magnetic fields by solenoids and a bar magnet • assess the impact of applications of magnetic fields on society	• plan, choose equipment or resources for, and perform a first-hand investigation to lift a specified weight by designing an electromagnet • perform a first-hand investigation to observe magnetic fields by mapping lines of force: – around a bar magnet – surrounding a straight current-carrying conductor – of a solenoid and present information showing the direction of the current using ⊗ or ⊙ and strength and direction of the field • identify data sources, gather, process and analyse information to explain one application of magnetic fields in households, such as: – telephone or stereo speakers – magnetic tape and use the available evidence to assess the impact of its use
6. Safety devices are important in household circuits	• discuss the effects of an electric shock from both a 240 volt AC mains supply and various DC voltages, from appliances, on the muscles of the body • identify the functions of circuit breakers, fuses and other safety devices in the home • outline the role of insulators in household appliances	• gather, process and analyse information from secondary sources and use the available evidence to assess the effect of different voltages on the muscles of the body and discuss whether the length of time of contact with the current increases the effect • gather, process and analyse information from secondary sources and use the available evidence to explain the use of insulators in electrical appliances and the impact of recent developments in the use of insulators for electricity

8.4 Moving About

Contextual Outline

Increased access to transport is a feature of today's society. Most people access some form of transport for travel to and from school or work and for leisure outings at weekends or on holidays. When describing journeys that they may have taken in buses or trains, they usually do so in terms of time or their starting point and their destination. When describing trips they may have taken in planes or cars, they normally use the time it takes, distance covered or the speed of the vehicle as their reference points. While distance and speed are fundamental to the understanding of kinematics and dynamics, very few people consider a trip in terms of energy, force or the momentum associated with a vehicle, even at low or moderate speeds.

The faster a vehicle is travelling, the further it will go before it is able to stop. Major damage can be done to other vehicles and to the human body, even at low speeds. This is because during a collision some or all of the vehicle's kinetic energy is dissipated through the vehicle and the object with which it collides. Further, the materials from which vehicles are constructed do not deform or bend as easily as the human body. Technological advances and systematic study of vehicle crashes have increased understanding of the interactions involved, the potential resultant damage and possible ways of reducing the effects of collisions. There are many safety devices now installed in or on vehicles, including seat belts and air bags. Modern road design takes into account ways in which vehicles can be forced to reduce their speed by strategically placing speed humps and speed dampeners.

Assumed Knowledge

Domain: knowledge and understanding:

Refer to the *Science Stages 4–5 Syllabus* for the following:

5.6.2a describe qualitatively the relationship between force, mass and acceleration

5.6.2b explain qualitatively the relationship between distance, speed and time

5.6.2c relate qualitatively acceleration to change in speed and/or direction as a result of a net force

5.6.2d analyse qualitatively common situations involving motion in terms of Newton's Laws.

Outcomes

The main course outcomes to which this module contributes are:

A student:

P2	applies the processes that are used to test and validate models, theories and laws of science with particular emphasis on first-hand investigations in physics
P4	describes applications of physics which affect society or the environment
P6	describes the forces acting on an object which cause changes in its motion
P7	describes the effects of energy transfers and energy transformations
P11	identifies and implements improvements to investigation plans
P12	discusses the validity and reliability of data gathered from first-hand investigations and secondary sources
P13	identifies appropriate terminology and report styles to communicate information and understanding in physics
P14	draws valid conclusions from gathered data and information
P15	implements strategies to work effectively as an individual or as a member of a team
P16	demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Vehicles do not typically travel at a constant speed	• compare estimates of the time taken, distance travelled and possible route for a range of vehicles to provide transport from one place to another • explain why it is useful to identify speed, direction and changes in speed and direction to describe differences in estimates of a journey • identify that a typical journey involves speed changes • recall average speed in terms of the qualitative relationship between distance and time • recall the relationship between distance, speed and time • apply mathematical models to the quantitative determination of average speed • distinguish between instantaneous and average speed of vehicles and other bodies • distinguish between scalar and vector quantities in equations • describe the motion of one body relative to another • compare instantaneous and average speed with instantaneous and average velocity	• plan, choose equipment or resources for, and perform a first-hand investigation to measure the average speed of an object or a vehicle and use SI units (symbols) for mathematical models • solve problems and analyse information using the formula $v_{AV} = \Delta \frac{r}{t}$ where r = displacement • present information graphically of: – displacement vs time – velocity vs time for objects with uniform and non-uniform linear velocity • identify data sources and perform an investigation to demonstrate whether the speedometer of a vehicle indicates instantaneous speed or average speed • process information to compare speed and velocity using mathematical models

2. An analysis of the external forces on vehicles helps to understand the effects of acceleration and deceleration

Students learn to:

- recall the qualitative relationship between force, mass and acceleration
- recall that acceleration is related to a change in speed and/or direction as a result of a net force
- identify that vector diagrams are a way of predicting resultant velocity or acceleration
- explain the need for a net external force to act in order to change the velocity of an object
- describe the actions that must be taken for a vehicle to change direction, speed up and slow down
- identify and assess the typical effects of external forces on bodies including:
  - friction between surfaces
  - air resistance
- define average acceleration as

  $$a_{av} = \frac{\Delta v}{\Delta t}$$

  therefore

  $$a_{av} = \frac{v-u}{t}$$
- define the terms ‘mass’ and ‘weight’ with reference to the effects of gravity
- outline the forces involved in causing a change in the velocity of a vehicle when:
  - coasting with no pressure on the accelerator
  - pressing on the accelerator
  - pressing on the brakes
  - passing over an icy patch on the road
  - climbing and descending hills
  - following a curve in the road
- interpret Newton’s Second Law of Motion and relate it to the equation

  $$\sum F = ma$$
- identify the net force in a wide variety of situations involving modes of transport and explain the consequences of the application of that net force in terms of Newton’s Second Law of Motion

Students:

- present and process information to analyse the origins and effects of external forces operating on a vehicle
- gather first-hand information about different situations where acceleration is positive or negative
- plan, choose equipment or resources for and perform a first hand investigation to demonstrate vector addition and subtraction
- gather information to identify how vectors are represented in equations and discuss the usefulness of using vector diagrams to assist solving problems
- plan, choose equipment or resources for, and perform a first-hand investigation to determine the mass of an object
- plan, choose equipment or resources for, and perform first-hand investigations to gather data and use available evidence to show the relationship between force, mass and acceleration using suitable apparatus
- solve problems and analyse information using

  $$\sum F = ma$$

  for a range of situations involving modes of transport

	Students learn to:	*Students:*
3. Moving vehicles have kinetic energy and energy transformations are an important aspect in understanding motion	• identify that a moving object possesses kinetic energy and that work transfers energy through the motion of a force • describe the energy transformations that occur in collisions • recall the law of conservation of energy	• solve problems and analyse information using appropriate models to determine the kinetic energy of the vehicles using the formula: $E_k = \frac{1}{2} mv^2$ and • analyse information to trace the energy transfers and transformation in collisions leading to irreversible distortions
4. Change of momentum relates to the forces acting on the vehicle or the driver	• recall Newton's Third Law qualitatively • define momentum as $p = mv$ • define impulse as the product of force and time • explain why momentum is conserved in collisions	• solve problems and analyse secondary data using $p = mv$ and $Impulse = Ft$ • perform first-hand investigations to gather data and analyse the change in momentum during collisions • solve problems that apply the principle of conservation of momentum to qualitatively and quantitatively describe the collision of a moving vehicle with: – a stationary vehicle – a cliff face – another vehicle moving in the opposite direction – another vehicle moving in the same direction

	Students learn to:	*Students:*
5. Safety devices are utilised to reduce the effects of changing momentum	• define the inertia of a vehicle as its tendency to remain in motion or at rest • recall Newton's First Law of Motion in qualitative terms • discuss reasons why Newton's First Law of Motion is not apparent in many real world situations • evaluate the effectiveness of some safety feature of motor vehicles with respect to the concepts of impulse and momentum • assess the reasons for the introduction of low speed zones and speed humps in built up areas and crumple zones on vehicles	• identify data sources, plan, choose equipment or resources for, and gather and process first-hand data and/or secondary information and analyse information about the potential danger presented by loose objects in a vehicle • identify data sources and gather, process and analyse information and use available evidence to assess the function of inertia reel safety belts • gather and analyse information and use available evidence to assess the difference between a lap, lap sash and a harness seatbelt in terms of reducing the effects of inertia in a collision • identify data sources, gather, process, analyse, present secondary information and use the available evidence to assess benefits of technologies for avoiding or reducing the effect of a collision
6. The models applied to motion and forces involving vehicles can be applied to a wide variety of situations	• discuss the range of situations in which the models used to analyse motion and forces in vehicles can be applied • describe how models assist in developing understandings about interactions	• solve problems and analyse information to apply the models developed to analyse motion and forces involving vehicles to other situations

8.5 The Cosmic Engine

Contextual Outline

The universe began with a singularity in space-time and thereafter has seen a continual movement of energy impelling, creating and organising matter. As part of this ongoing process, the sun formed over 4 x 10^9 years ago from a cloud of gas and dust whose collapse was triggered by a supernova explosion. The condensing gas and dust that formed the sun contained all its original elements plus the elements formed and inserted during the supernova explosion.

Our solar system is powered by the energy from that original event. More energy is released by nuclear reactions in the core of the sun and driven outwards as electromagnetic and particle energy. Energy driving the Earth's atmospheric circulation and ocean currents is derived directly and indirectly from this source combined with the energy radiated from the Earth's core and surface.

The balance between incoming solar radiation and outgoing long-wave radiation defines the Earth's radiation budget or balance. For the Earth's surface temperature to remain constant, the energy added to the Earth's surface and atmosphere must be, in the long-term, exactly balanced by emissions. The transfer of energy to maintain thermal equilibrium over the globe relates to the laws of thermodynamics and the mechanisms of heat transfer.

Assumed Knowledge

Domain: knowledge and understanding:

Refer to the *Science Stages 4–5 Syllabus* for the following:

5.6.5a identify that energy may be released from the nuclei of atoms

5.7.1a describe the features and location of protons, neutrons and electrons in the atom

5.9.1a discuss current scientific thinking about the origin of the universe

5.9.1c describe some of the difficulties in obtaining information about the universe

5.9.3a relate some major features of the universe to theories about the formation of the universe

5.9.3b describe some changes that are likely to take place during the life of a star.

Outcomes

The main course outcomes to which this module contributes are:

A student:

P1 outlines the historical development of major principles, concepts and ideas in physics

P4 describes applications of physics which affect society or the environment

P5 describes the scientific principles employed in particular areas of physics research

P6 describes the forces acting on an object which cause changes in its motion

P7 describes the effects of energy transfers and energy transformations

P9 describes the relationship between force and potential energy in fields

P10 describes theories and models in relation to the origins of matter and relates these to the forces involved

P11 identifies and implements improvements to investigation plans

P12 discusses the validity and reliability of data gathered from first-hand investigations and secondary sources

P13 identifies appropriate terminology and reporting styles to communicate information and understanding in physics

P14 draws valid conclusions from gathered data and information

P15 implements strategies to work effectively as an individual or as a member of a team

P16 demonstrates positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Ours is just one star in the galaxy and ours is just one galaxy in the universe	• outline the historical development of models of the universe from Aristotle to Newton • describe qualitatively current scientific thinking about the structure of the universe	• identify data sources, gather, process and analyse information to assess one of the models of the universe developed from the time of Aristotle to Newton and identify the limitations placed on the development of the model by the technology of the time
2. The first minutes of the universe released energy which changed to matter, forming stars and galaxies	• recall the features and location of protons, neutrons and electrons in the atom • describe qualitatively some features of quarks • outline the discovery of the expansion of the universe by Hubble, following its earlier prediction by Friedmann • recall current scientific thinking about the origin of the universe • give an account of the transformation of radiation into matter which followed the 'big bang' • identify that Einstein described the equivalence of energy and mass • outline how the accretion of galaxies and stars occurred through: – expansion and cooling of the universe – subsequent loss of particle kinetic energy – increased gravitational attraction between particles – lumpiness of the gas cloud that then allows gravitational collapse	• identify data sources and gather secondary information to describe the probable origins of the universe • process information to assess the relationship between a theory and the evidence supporting it using the work of Freidmann, predicting the expansion of the universe years before it was discovered

	Students learn to:	*Students:*
3. Stars have a limited life span and may explode to form supernovas	• recall the inverse square law of intensity of light and use it to relate the brightness of a star to its luminosity and distance from the observer • define the relationship between the temperature of a body and the dominant wavelength of the radiation emitted from that body • explain that the surface temperature of a star is related to its colour • describe a Hertzsprung-Russell diagram as the graph of a star's luminosity against its colour or temperature • identify energy sources characteristic of each star group, including main sequence, red giants, and white dwarfs • identify that energy may be released from the nuclei of atoms • describe the nature of emissions from the nuclei of atoms as radiation of alpha α, beta β, and gamma γ rays in terms of: – ionising power – penetrating power – effect of magnetic field – effect of electric field	• gather secondary information to relate brightness of an object to its luminosity and distance • plan, choose equipment or resources for, and perform first-hand investigations and gather information to relate colour of a hot object to its temperature • gather information from secondary sources to demonstrate the star groups that emerge when many stars are plotted on a Hertzsprung-Russell diagram • process and analyse information using the Hertzsprung-Russell diagram to examine the variety of star groups, including main sequence, red giants, and white dwarfs • gather information from secondary sources to examine the Hertzsprung-Russell diagram of open and globular clusters and use available evidence to deduce the life cycle of a star • perform a first-hand investigation to gather information to determine the penetrating power of alpha, beta and gamma radiation on a range of materials • identify data sources, gather, process and analyse information to discuss the issues associated with maintaining fusion reactions on Earth

	Students learn to:	*Students:*
4. The solar system is held together by gravity	• outline the development and current structure of the solar system • define Newton's Law of Universal Gravitation $F = G\frac{m_1 m_2}{d^2}$ • describe a gravitational field in the region surrounding a massive object in terms of its effects on other masses in it • define the term orbital velocity and the quantitative and qualitative relationship between orbital velocity, the gravitational constant, mass of the satellite and the radius of the orbit using Kepler's Third Law $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$	• present information and use available evidence to discuss the factors affecting the size of the gravitational force • solve problems and analyse information using $F = G\frac{m_1 m_2}{d^2}$ • solve problems and analyse information using Kepler's Third Law: $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$
5. The sun is a typical star, emitting electromagnetic radiation and particles that influence the Earth	• identify the nature of emissions reaching the Earth from the sun • describe the particulate nature of solar winds • outline the cyclic nature of sunspot activity and its impact on Earth through solar winds • describe sunspots as representing regions of strong magnetic activity and lower temperature	• identify data sources, gather and process information and use available evidence to assess the effects of sunspot activity on the Earth's power grid and communications • present information to schematically represent the path of solar winds as they flow around the Earth
6. The conditions at the surface of the Earth are influenced by the interactions between physical phenomena generated by both the sun and the Earth	• explain how the internal structure and composition of the Earth produce a magnetic field protecting the Earth from excessive ionising radiation • identify that the Earth's magnetic field traps protons and electrons from space in the form of Van Allen belts • outline the composition of the atmosphere and its effect on the penetration of electromagnetic radiation • define black bodies in terms of the heat radiated and absorbed and compare the Earth to a black body	• plan, choose equipment or resources for, and perform a first-hand investigation to gather and use available information to demonstrate the absorption of thermal energy and other forms of radiation such as light and its re-radiation from solid and liquid objects • gather, process and analyse information on the role of the ozone layer in protecting life on Earth • gather information to demonstrate that a hole in the side of an otherwise opaque hollow container is the most perfect black body that can be constructed

9 Content: Physics Stage 6 HSC Course

9.1 Physics Skills

During the HSC course, it is expected that students will further develop skills in planning and conducting investigations, communicating information and understanding, scientific thinking and problem solving and working individually and in teams. Each module specifies content through which skill outcomes can be achieved. Teachers should develop activities based on that content to provide students with opportunities to develop the full range of skills.

HSC Course Outcomes	Content
A student: H11. justifies the appropriateness of a particular investigation plan	*Students:* **11.1 identify data sources to:** a) analyse complex problems to determine appropriate ways in which each aspect may be researched b) determine the type of data that needs to be collected and explain the qualitative or quantitative analysis that will be required for this data to be useful c) identify the orders of magnitude that will be appropriate and the uncertainty that may be present in the measurement of data d) identify and use correct units for data that will be collected e) recommend the use of an appropriate technology or strategy for data collection or information gathering that will assist efficient future analysis
	11.2 plan first-hand investigations to: a) demonstrate the use of the terms 'dependent' and 'independent' to describe variables involved in the investigation b) identify variables that needed to be kept constant, develop strategies to ensure that these variables are kept constant, and demonstrate the use of a control c) design investigations that allow valid and reliable data and information to be collected d) describe and trial procedures to undertake investigations and explain why a procedure, a sequence of procedures or the repetition of procedures is appropriate e) predict possible issues that may arise during the course of an investigation and identify strategies to address these issues if necessary
	11.3 choose equipment or resources by: a) identifying and/or setting up the most appropriate equipment or combination of equipment needed to undertake the investigation b) carrying out a risk assessment of intended experimental procedures and identifying and addressing potential hazards c) identifying technology that would be used during investigation determining its suitability and effectiveness for its potential role in the procedure or investigation d) recognising the difference between destructive and non-destructive testing of material and analysing potentially different results from these two procedures

HSC Course Outcomes	Content
A student: H12. evaluates ways in which accuracy and reliability could be improved in investigations	*Students:* **12.1 perform first-hand investigations by:** a) carrying out the planned procedure, recognising where and when modifications are needed and analysing the effect of these adjustments b) efficiently undertaking the planned procedure to minimise hazards and wastage of resources c) disposing carefully and safely of any waste materials produced during the investigation d) identifying and using safe work practices during investigations
	12.2 gather first-hand information by: a) using appropriate data collection techniques, employing appropriate technologies, including data loggers and sensors b) measuring, observing and recording results in accessible and recognisable forms, carrying out repeat trials as appropriate
	12.3 gather information from secondary sources by: a) accessing information from a range of resources, including popular scientific journals, digital technologies and the Internet b) practising efficient data collection techniques to identify useful information in secondary sources c) extracting information from numerical data in graphs and tables as well as written and spoken material in all its forms d) summarising and collating information from a range of resources e) identifying practising male and female Australian scientists, and the areas in which they are currently working and in formation about their research
	12.4 process information to: a) assess the accuracy of any measurements and calculations and the relative importance of the data and information gathered b) identify and apply appropriate mathematical formulae and concepts c) best illustrate trends and patterns by selecting and using appropriate methods, including computer assisted analysis d) evaluate the validity of first-hand and secondary information and data in relation to the area of investigation e) assess the reliability of first-hand and secondary information and data by considering information from various sources f) assess the accuracy of scientific information presented in mass media by comparison with similar information presented in scientific journals

HSC Course Outcomes	Content
A student: H13. uses terminology reporting styles appropriately and successfully to communicate information and understanding	*Students:* **13.1 present information by:** a) selecting and using appropriate text types or combinations thereof, for oral and written presentations b) selecting and using appropriate media to present data and information c) selecting and using appropriate methods to acknowledge sources of information d) using symbols and formulae to express relationships and using appropriate units for physical quantities e) using a variety of pictorial representations to show relationships and present information clearly and succinctly f) selecting and drawing appropriate graphs to convey information and relationships clearly and accurately g) identifying situations where use of a curve of best fit is appropriate to present graphical information
H14. assesses the validity of conclusions drawn from gathered data and information	**14.1 analyse information to:** a) identify trends, patterns and relationships as well as contradictions in data and information b) justify inferences and conclusions c) identify and explain how data supports or refutes an hypothesis, a prediction or a proposed solution to a problem d) predict outcomes and generate plausible explanations related to the observations e) make and justify generalisations f) use models, including mathematical ones, to explain phenomena and/or make predictions g) use cause and effect relationships to explain phenomena h) identify examples of the interconnectedness of ideas or scientific principles
	14.2 solve problems by: a) identifying and explaining the nature of a problem b) describing and selecting from different strategies, those which could be used to solve a problem c) using identified strategies to develop a range of possible solutions to a particular problem d) evaluating the appropriateness of different strategies for solving an identified problem
	14.3 use available evidence to: a) design and produce creative solutions to problems b) propose ideas that demonstrate coherence and logical progression and include correct use of scientific principles and ideas c) apply critical thinking in the consideration of predictions, hypotheses and the results of investigations d) formulate cause and effect relationships

9.2 Space

Contextual Outline

Humans have progressed in the last thousand years from animal powered transport on land and wind powered ships on water to vehicles that are sufficiently sophisticated to allow travel beyond the Earth into the solar system.

Scientists have drawn on advances in areas such as aeronautics, materials science, robotics, electronics, medicine and energy production to develop viable spacecraft. Perhaps the most dangerous parts of any space mission are the launch, re-entry and landing. A huge force is required to propel the rocket a sufficient distance from the Earth so that it is able to either escape the Earth's gravitational pull or maintain an orbit. There are many factors to be taken into account in choosing the time of day for a rocket to be launched. These include consideration of: the weather predictions for the launch date; whether there is an expectation that the craft will rendezvous with another orbiting body; and whether the landing site for an aborted mission is appropriate. Following a successful mission, re-entry through the Earth's atmosphere provides further challenges to scientists if astronauts are to return to Earth safely.

Rapid advances in technologies over the past thirty years have allowed the exploration of not only the moon, but the solar system and, to an increasing extent, the universe. Space exploration is becoming more viable. Information and research undertaken in space programs have impacted on society through the development of such things as personal computers, advanced medical equipment, communication satellites, improved weather forecasting and accurate mapping of natural resources. Speculation continues as we consider where humans will be travelling in the next one thousand years. Meanwhile, space research and exploration of space increase understanding of the Earth's own environment, the solar systems and the universe.

Outcomes

The main course outcomes to which this module contributes are:

A student:

H1	evaluates how major advances in scientific understanding and technology have changed the direction or nature of scientific thinking
H2	analyses the ways in which models, theories and laws in physics have been tested and validated
H4	assesses the impact of applications of physics on society and the environment
H6	explains events in terms of Newton's Laws, Law of Conservation of Momentum and relativity
H7	explains the effect of energy transfers and transformation
H9	explains the effects of electric, magnetic and gravitational fields
H11	justifies the appropriateness of a particular investigation plan
H12	evaluates ways in which accuracy and reliability could be improved in investigations
H13	uses terminology and reporting styles appropriately and successfully to communicate information and understanding
H14	assesses the validity of conclusions drawn from gathered data and information
H15	explains why an investigation is best undertaken individually or by a team
H16	justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

1. The Earth has a gravitational field that exerts a force on objects both on it and around it

Students learn to:

- define weight as the force on an object due to a gravitational field
- define gravitational potential energy as the work done to move an object from a very large distance away to a point in a gravitational field

  $E_p = -G\frac{m_1 m_2}{r}$

Students:

- perform an investigation and gather information to determine a value for acceleration due to gravity using pendulum motion, computer assisted technology and/or other strategies and explain possible sources of variations from the value 9.8 ms^{-2}
- gather secondary information to identify the value of acceleration due to gravity on other planets
- analyse information using the expression

  $F = mg$

  to determine the weight force for a body on Earth and the weight force for the same body on other planets

2. Many factors have to be taken into account to achieve a successful rocket launch, maintain a stable orbit and return to Earth

Students learn to:

- describe the trajectory of an object undergoing projectile motion within the Earth's gravitational field in terms of horizontal and vertical components
- describe Galileo's analysis of projectile motion
- explain the concept of escape velocity in terms of the:
  - gravitational constant
  - mass and radius of the planet
- discuss Newton's analysis of escape velocity
- use the term 'g forces' to explain the forces acting on an astronaut during launch
- compare the forces acting on an astronaut during launch with what happens during a roller coaster ride
- discuss the impact of the Earth's orbital motion and its rotational motion on the launch of a rocket
- analyse the changing acceleration of a rocket during launch in terms of the:
  - Law of Conservation of Momentum
  - forces experienced by astronauts
- analyse the forces involved in uniform circular motion for a range of objects, including satellites orbiting the Earth
- compare qualitatively and quantitatively low Earth and geo-stationary orbits

Students:

- solve problems and analyse information to calculate the actual velocity of a projectile from its horizontal and vertical components
- solve problems and analyse information using:

  $$v = u + at$$

  $$v_x^2 = u_x^2$$

  $$v_y^2 = u_y^2 + 2\,a_y \Delta y$$

  $$\Delta x = u_x t$$

  $$\Delta y = u_y t + \frac{1}{2} a_y t^2$$

  in relation to projectile motion
- perform a first-hand investigation, gather secondary information and analyse data to describe factors, such as initial and final velocity, maximum height reached, range, time of flight of a projectile, and quantitatively calculate each for a range of situations by using simulations, data loggers and computer analysis
- identify data sources, gather and process information from secondary sources to investigate conditions during launch and use available evidence to and explain why the forces acting on an astronaut increase to approximately 3W during the initial periods of the launch
- identify data sources, gather, analyse and present information on the contribution of Tsiolkovsky, Oberth, Goddard, Esnault-Pelterie, O'Neill or von Braun to the development of space exploration
- perform an investigation that demonstrates that the closer a satellite is to its parent body, the faster it moves to maintain a stable orbit

	Students learn to:	*Students:*
	• discuss the importance of Newton's Law of Universal Gravitation in understanding and calculating the motion of satellites • describe how a slingshot effect is provided by planets for space probes • account for the orbital decay of satellites in low Earth orbit • discuss issues associated with safe re-entry into the Earth's atmosphere and landing on the Earth's surface • identify that there is an optimum angle for re-entry into the Earth's atmosphere and the consequences of failing to achieve this angle	• solve problems and analyse information to calculate centripetal force acting on a satellite undergoing uniform circular motion about the Earth • solve problems and analyse information using: $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ • plan, choose equipment or resources for, and perform an investigation to model the effect that removal of the Earth's gravitational force would have on the direction of satellite motion • plan, choose equipment or resources for, and perform a first-hand investigation to model the effect of friction and heat on a range of materials, including metals and ceramics
3. Future space travel and exploration will entail a combination of new technologies based on current and emerging knowledge	• discuss the limitation of current maximum velocities being too slow for extended space travel to be viable • describe difficulties associated with effective and reliable communications between satellites and earth caused by: – distance – van Allen radiation belts – sunspot activity	• gather, process, analyse and present information to compare the use of microwave and radiowave technology as effective communication strategies for space travel

4. Current and emerging understanding about time and space has been dependent upon earlier models of the transmission of light

Students learn to:

- outline the features of the aether model for the transmission of light
- describe and evaluate the Michelson-Morley attempt to measure the relative velocity of the Earth through the aether
- discuss the role of critical experiments in science, such as Michelson-Morley's, in making determinations about competing theories
- outline the nature of inertial frames of reference
- discuss the principle of relativity
- identify the significance of Einstein's assumption of the constancy of the speed of light
- recognise that if c is constant then space and time become relative
- discuss the concept that length standards are defined in terms of time with reference to the original metre
- identify the usefulness of discussing space/time, rather than simple space
- account for the need, when considering space/time, to define events using four dimensions
- explain qualitatively and quantitatively the consequence of special relativity in relation to:
  - the relativity of simultaneity
  - the equivalence between mass and energy
  - length contraction
  - time dilation
- discuss the implications of time dilation and length contraction for space travel

Students:

- perform an investigation and gather first-hand or secondary data to model the Michelson-Morley experiment
- perform an investigation to help distinguish between non-inertial and inertial frames of reference
- analyse and interpret some of Einstein's thought experiments involving mirrors and trains and discuss the relationship between thought and reality
- analyse information to discuss the relationship between theory and the evidence supporting it, using Einstein's predictions based on relativity that were made many years before evidence was available to support it
- solve problems and analyse information using:

$$L_v = L_0\sqrt{1 - \frac{v^2}{c^2}}$$

and

$$t_v = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

- gather, process, analyse information and use available evidence to discuss the relative energy costs associated with space travel

9.3 Motors and Generators

Contextual Outline

Electricity is a convenient and flexible form of energy. It can be generated and distributed with comparative ease, and most importantly, it can be readily converted into other forms of energy such as heat, light, sound or mechanical energy. Electricity is a key element in the development of industrialised nations.

There are many examples of electric motors both around the home: refrigerators; washing machines; vacuum cleaners; and in the community: industrial motors and trains. The design of a motor for an electrical appliance requires consideration of whether it will run at a set speed, how much power it must supply, whether it will be powered by AC or DC and what reliability is required. The essentials of an electric motor are the supply of electrical energy to a coil in a magnetic field causing it to rotate.

The generation of large quantities of electrical power requires relative motion between a magnetic field and a coil. In the generator, mechanical energy is being converted into electrical energy while the opposite occurs in the electric motor. Once generated, electricity must be distributed over long distances from the power station to cities and towns. Transmission lines carry the electrical energy at a high voltage from the generator and transformers eventually reduce the voltage to that required by the consumer.

The electricity produced by most generators is in the form of alternating current. In general AC generators, motors and other electrical equipment are simpler, cheaper and more reliable than their DC counterparts. AC electricity can be easily transformed into higher or lower voltages making it more versatile than DC electricity. Since the frequency of AC electricity can be precisely controlled, it is used in motors that require accurate speed, such as clocks and tape recorders.

Outcomes

The main course outcomes to which this module contributes are:

A student:

- H3 assesses the impact of particular advances in physics on the development of technologies
- H4 assesses the impact of applications of physics on society and the environment
- H7 explains the effect of energy transfers and transformation
- H8 analyses wave interactions and explains the effects of those interactions
- H9 explains the effects of electric, magnetic and gravitational fields
- H11 justifies the appropriateness of a particular investigation plan
- H12 evaluates ways in which accuracy and reliability could be improved in investigations
- H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding
- H14 assesses the validity of conclusions drawn from gathered data and information
- H15 explains why an investigation is best undertaken individually or by a team
- H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science.

1. Motors use the effect of forces on current-carrying conductors in magnetic fields

Students learn to:

- identify that moving charged particles in a magnetic field experience a force
- discuss the effect, on the magnitude of the force on a current-carrying conductor, of variations in:
  - the strength of the magnetic field in which it is located
  - the magnitude of the current in the conductor
  - the length of the conductor in the external magnetic field
  - the angle between the direction of the external magnetic field and the direction of the length of the conductor
- describe qualitatively and quantitatively the force on long parallel current-carrying conductors:

  $$\frac{F}{l} = k\frac{I_1 I_2}{d}$$
- define torque as the turning moment of a force using:

  $$\tau = Fd$$
- identify the forces experienced by a current-carrying loop in a magnetic field and describe the net result of the forces
- account for the motor effect due to the force acting on a current-carrying conductor in a magnetic field
- describe the main features of a DC electric motor
- discuss the importance of the invention of the commutator for developing electric motors
- describe the role of the metal split ring and the brushes in the operation of the commutator
- describe how the required magnetic fields can be produced either by current-carrying coils or permanent magnets

Students:

- identify data sources, gather, analyse and present information to discuss the Van Allen radiation belts as examples of motion of charged particles in a field
- perform a first-hand investigation to demonstrate the motor effect
- solve problems and analyse information about the force on current-carrying conductors in magnetic fields using $F = BI\ell$
- solve problems and analyse information about simple motors using:

  $$\frac{F}{l} = k\frac{I_1 I_2}{d}$$ and

  $$\tau = nBIA\cos\theta$$
- gather and process secondary information to analyse the function of the parts of a commutator
- identify data sources, gather and process information to qualitatively describe the application of the motor effect in:
  - the galvanometer
  - the loudspeaker

	Students learn to:	*Students:*
2. The relative motion between a conductor and magnetic field is used to generate an electrical voltage	• outline Michael Faraday's discovery of the generation of an electric current by a moving magnet • define magnetic field strength B as magnetic flux density • explain the concept of magnetic flux in terms of magnetic flux density and surface area • explain generated potential difference as the rate of change of magnetic flux through a circuit • account for Lenz's Law in terms of conservation of energy and relate it to the production of back emf in motors • explain that, in electric motors, back emf opposes the supply emf • apply Lenz's Law to the production of eddy currents	• perform an investigation to model the generation of an electric current by moving a magnet in a coil or a coil near a magnet • plan, choose equipment or resources for, and perform a first-hand investigation to predict and verify by gathering and analysing information about the generated electric current when: – the distance between the coil and magnet is varied – the strength of the magnet is varied – the relative motion between the coil and the magnet is varied • gather, analyse and present information to explain how the principle of induction applies to cooktops in electric ranges • gather secondary information to identify how eddy currents have been utilised in switching devices and electromagnetic braking
3. Generators are used to provide large scale power production in isolated areas and as a backup in emergency situations	• identify the main components of a generator • compare the structure and function of a generator to an electric motor • describe the operation of an AC and a DC generator • discuss the energy losses that occur as energy is fed through transmission lines from the generator to the consumer • analyse the effects of the development of AC and DC generators on society and the environment • assess evidence about the physiological effects on humans living near high voltage power lines	• perform first-hand investigations to produce direct current using voltaic cells • plan, choose equipment or resources for, and perform a first-hand investigation to demonstrate the production of an alternating current • gather secondary information to compare advantages and disadvantages of AC and DC generators and relate these to their use • gather and analyse information to identify how transmission lines are: – insulated from supporting structures – protected from lightning strikes

	Students learn to:	*Students:*
4. Transformers allow generated voltage to be either increased or decreased before it is used	• explain the purpose and principles of transformers in electrical circuits • compare step-up and step-down transformers • determine the relationship between the ratio of the number of turns in the primary and secondary coils and the ratio of primary to secondary voltage • explain why voltage transformations are related to conservation of energy • explain the role of transformers in electricity sub-stations • discuss why some electrical appliances in the home that are connected to the mains domestic power supply use a transformer • analyse the impact of the development of transformers on society	• perform an investigation to model the structure of a transformer to demonstrate how secondary voltage is produced • solve problems and analyse information about transformers using: $\frac{v_p}{v_s} = \frac{n_p}{n_s}$ • gather, analyse and use available evidence to discuss how difficulties of heating caused by eddy currents in transformers may be overcome • gather and analyse information and use available evidence to assess the need for transformers in the transfer of electrical energy from a power station to its point of use
5. Motors are used in industries and the home usually to convert electrical energy into more useful forms of energy	• describe the main features of an AC electric motor • explain that AC motors usually produce low power and relate this to their use in power tools • explain the advantages of induction motors	• perform an investigation to demonstrate the principle of an AC induction motor and discuss why the majority of motors are AC induction motors • gather, process and analyse information to identify some of the energy transfers and transformations involving the conversion of electrical energy into more useful forms in the home and industry

9.4 From Ideas to Implementation

Contextual outline

By the beginning of the twentieth century, many of the pieces of the physics puzzle seemed to be falling into place. The wave model of light had successfully explained interference, diffraction and the wavelengths at the extremes of the visible spectrum had been estimated. The invention of a pump that would evacuate tubes to 10^{-4} atmospheres allowed the investigation of cathode rays. X-rays would soon be confirmed as electromagnetic radiation and patterns in the periodic table appeared to be nearly complete. The nature of cathode rays was resolved with the measurement of the charge on the electron soon to follow. There was a small number of experimental observations still unexplained but this, apparently complete, understanding of the world of the atom was about to be challenged.

The exploration of the atom was well and truly inward bound by this time and, as access to greater amounts of energy became available, the journey of physics moved further and further into the study of subatomic particles. Careful observation, analysis, imagination and creativity throughout the early part of the twentieth century developed a more complete picture of the nature of electromagnetic radiation and matter. The journey taken into the world of the atom has not remained isolated in laboratories. The phenomena discovered by physicists have, with increasing speed, been channelled into technologies, such as computers, to which society has ever-increasing access. These technologies have, in turn, often assisted physicists in their search for further knowledge and understanding of natural phenomena at the sub-atomic level.

Outcomes

The main course outcomes to which this module contributes are:

A student:

H1 evaluates how major advances in scientific understanding and technology have changed the direction or nature of scientific thinking

H2 analyses the ways in which models, theories and laws in physics have been tested and validated

H3 assesses the impact of particular advances in physics on the development of technologies

H4 assesses the impact of applications of physics on society and the environment

H5 identifies possible future directions of research in physics

H8 analyses wave interactions and explains the effects of those interactions

H9 explains the effects of electric, magnetic and gravitational fields

H10 describes the nature of electromagnetic radiation and matter in terms of the particles

H11 justifies the appropriateness of a particular investigation plan

H12 evaluates ways in which accuracy and reliability could be improved in investigations

H13 uses reporting styles and terminology appropriately and successfully to communicate information and understanding

H14 assesses the validity of conclusions drawn from gathered data and information

H15 explains why an investigation is best undertaken individually or by a team

H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Increased understandings of cathode rays led to the development of television	• explain that cathode ray tubes allowed the manipulation of a stream of charged particles • explain why the apparent inconsistent behaviour of cathode rays caused debate as to whether they were charged particles or electromagnetic waves • identify that charged plates produce an electric field • describe quantitatively the force acting on a charge moving through a magnetic field $F = qvB \sin \theta$ • discuss qualitatively the electric field strength due to a point charge, positive and negative charges and oppositely charged parallel plates • describe quantitatively the electric field due to oppositely charged parallel plates • outline Thomson's experiment to measure the charge/mass ratio of an electron • outline the role in a cathode ray tube of: – electrodes in the electron gun – the electric field – the fluorescent screen • outline applications of cathode rays in oscilloscopes, electron microscopes and television sets • discuss the impact of increased understandings of cathode rays and the development of the oscilloscope on experimental physics	• perform an investigation and gather first-hand information to observe the occurrence of different striation patterns for different pressures in discharge tubes • perform an investigation and gather first-hand information to demonstrate and identify properties using discharge tubes: – containing a maltese cross – containing electric plates – with a fluorescent display screen – containing a glass wheel and analyse the information gathered to determine the charge on the cathode rays • solve problem and analyse information using: $F = qvB \sin \theta$ and $E = \frac{V}{d}$ • gather, analyse and process information on the use of electrically charged plates and point charges in photocopying machines and lightning conductors • gather secondary information to identify the use of magnetic fields in television sets

	Students learn to:	*Students:*
2. The reconceptualisation of the model of light led to an understanding of the photoelectric effect and black body radiation	• explain qualitatively Hertz's experiments in measuring the speed of radio waves and how they relate to light waves • describe Hertz's observation of the effect of a radio wave on a receiver and the photoelectric effect he produced but failed to investigate • outline applications of the production of electromagnetic waves by oscillating electric charges in radio antennae • identify Planck's hypothesis that radiation emitted and absorbed by the walls of a black body cavity is quantised • identify Einstein's contribution to quanta and its relation to black body radiation • explain the particle model of light in terms of photons with particular energy and frequency • identify the relationships between photon energy, frequency, speed of light and wavelength: $E = hf$ and $c = f\lambda$	• perform an investigation to demonstrate the production and reception of radio waves • perform a first-hand investigation to demonstrate the photoelectric effect • identify data sources, gather, process and analyse information and use available evidence to assess Einstein's contribution to quanta and their relation to black body radiation • identify data sources gather, process and present information to summarise the use of the photoelectric effect in: – breathalysers – solar cells – photocells • solve problems and analyse information using: $E = hf$ and $c = f\lambda$ • identify data sources, gather and process information to discuss Einstein and Planck's debate about whether science research is removed from social and political forces

	Students learn to:	*Students:*
3. Limitations of past technologies and increased research into the structure of the atom resulted in the invention of transistors	• describe the de Broglie model of electrons in orbits around atoms • identify that some electrons in solids are shared between atoms and move freely • describe the difference between conductors, insulators and semiconductors in terms of band structures and relative electrical resistance • identify absences of electrons in a nearly full band as holes, and recognise that both electrons and holes help to carry current • compare qualitatively the relative number of free electrons that can drift from atom to atom in conductors, semiconductors and insulators • identify that the use of germanium in early transistors is related to lack of ability to produce other materials of suitable purity • explain why silicon became the preferred raw material for transistors • describe how 'doping' a semiconductor can change its electrical properties • identify differences in p and n-type semiconductors in terms of the relative number of negative charge carriers and positive holes • discuss differences between solid state and thermionic devices and discuss why solid state devices replaced thermionic devices	• perform an investigation to model the difference between conductors, insulators and semiconductors in terms of band structures • perform an investigation to demonstrate a model for explaining the behaviour of semiconductors, including the creation of a hole or positive charge on the atom that has lost the electron and the movement of electrons and holes in opposite directions when an electric field is applied across the semiconductor • gather, process and present secondary information to discuss how shortcomings in available technology lead to an increased knowledge of the properties of materials with particular reference to the invention of the transistor • gather, process and analyse secondary information to describe the relationship in solar cells between the photoelectric effect, semiconductors, electric fields and current • identify data sources, gather, process, analyse information and use available evidence to assess the impact of the invention of transistors on society with particular reference to their use in microchips and microprocessors

	Students learn to:	*Students:*
4. Investigations into the electrical properties of particular metals at different temperatures led to the identification of superconductivity and the exploration of possible applications	• outline the methods used by the Braggs to determine crystal structure and assess the impact of their contribution to an understanding of crystal structure • explain that metals possess a crystal lattice structure • identify that the conducting properties of metals are related to the large number of electrons able to drift through their crystal lattice structure • discuss the relationship between drift velocity and: – the density of electrons – the cross sectional area of wire – the electronic charge • discuss how the lattice impedes the paths of electrons causing heat to be generated • identify that superconductors, while still having lattices, allow the electrons to pass through unimpeded with no energy loss at particular temperatures • explain current theory that suggests that superconductors are conducting materials that, at specific temperatures, force electrons to pair and, through interactions with the crystal lattice, are ultimately able to form an unimpeded orderly stream • discuss the advantages of using superconductors and identify current limitations to their use	• plan, choose equipment or resources for, and perform a first-hand investigation to observe the heating effects of current in a range of conductors • process information to identify some of the metals, metal alloys and compounds that have been identified as exhibiting the property of superconductivity and the critical temperatures at which they operate • perform an investigation and gather first-hand information to observe magnetic levitation and the way the magnet is held in position by superconducting material • analyse information about magnetic levitation to explain why a magnet is able to hover above a superconducting material that has reached the temperature at which it is superconducting • gather and process information to describe how superconductors and the effects of magnetic fields have been applied to develop the maglev train • gather and process information to discuss possible applications of superconductivity and the effects of those applications on computers, generators and motors and transmission of electricity through power grids • process information to recall the states of matter and their properties and debate whether superconductivity is a new 'state'

9.5 Option — Geophysics

Contextual Outline

Geophysics is the application of physical theories and measurement to the investigation of the planet we inhabit. Geophysical studies may involve large-scale problems such as the Earth's structure and behaviour (solid earth geophysics) and problems associated with the exploration of the crust for minerals and engineering purposes (exploration geophysics).

Both solid earth geophysics and exploration geophysics use similar instrumentation and methods to study phenomena, such as gravitation, the Earth's magnetic field, radioactivity and the behaviour of seismic waves. Using an understanding of Earth material properties, geophysicists explore the Earth in ways that human senses cannot. Some of the properties of rocks that geophysicists deal with are elasticity, density, magnetic susceptibility, magnetisation and both electrical and thermal conductivity.

Geophysical investigations provide society with benefits, such as energy resources, minerals, hazard minimisation and an understanding of the complex planet we inhabit.

Outcomes

The main course outcomes to which this module contributes are:

A student:

- H1 evaluates how major advances in scientific understanding and technology have changed the direction or nature of scientific thinking
- H4 assesses the impact of particular applications of physics on society and the environment
- H8 analyses wave interactions and explains the effects of those interactions
- H9 explains the effects of electric, magnetic and gravitational fields
- H10 describes the nature of electromagnetic radiation and matter in terms of the particles
- H11 justifies the appropriateness of a particular investigation plan
- H12 evaluates ways in which accuracy and reliability could be improved in investigations
- H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding
- H14 assesses the validity of conclusions drawn from gathered data and information
- H15 explains why an investigation is best undertaken individually or by a team
- H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for a critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Geophysics involves the measurement of physical properties of the Earth	• outline the evolution of geophysical investigation and its relationship with improvements in instrumentation • describe the properties of earth materials that are studied in geophysics — particularly elasticity, density, thermal, magnetic and electrical properties • identify the principal methods used in geophysics as seismic, gravity, magnetic, palaeomagnetic, electrical, electromagnetic, radiometric and geothermal and describe the type of information that each of these methods can provide • deduce the types of methods that might provide useful information given the properties of the materials in an area	• identify data sources, gather and process information to discuss Huygen's and Newton's investigation of the shape of the Earth using pendulum measurements • plan, choose equipment or resources for, and perform first-hand investigations to gather data and use the available evidence to analyse the variation in density of different rock types • solve problems, analyse information and use available evidence to compare the thermal properties of different substances

	Students learn to:	*Students:*
2. Some physical phenomena such as gravitation and radiation provide information about the Earth at a distance from it	• recall the variation in properties of electromagnetic waves • describe how absorption and reflection of radiation can provide information about the reflecting surface • explain how remote sensing techniques can be used to monitor climate, vegetation and pollution • summarise uses of the remote sensing of radiation in mineral exploration • explain why gravitational attraction of a small mass at a point can be studied as the vector sum of attraction by a number of bodies • outline reasons why the gravitational field of the Earth varies • describe how the paths of satellites are used to study the Earth's gravity • outline the structure and function of a gravity meter • describe the purpose of data reduction in gravity surveys • recount the steps involved in gravity data reduction — latitude correction, free air correction and Bouguer correction • identify and describe the uses of gravity methods in resource exploration and archaeology	• plan, choose equipment or resources for, and perform a first-hand investigation to gather data to demonstrate the relationship between the nature of a surface and the radiation reflected from it • process information to describe the significance of Jean Richer's experiments with the pendulum in disproving the spherical Earth hypothesis • solve problems and analyse information to calculate the mass of the Earth given g and the diameter of the Earth • perform an investigation and gather and analyse data to identify the value of g using a pendulum • solve problems and analyse information to calculate the mass of the Earth given the period of a satellite: $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ • perform an investigation, using second-hand data, to discuss changes that occur during data reduction of gravity data

	Students learn to:	*Students:*
3. Seismic methods provide information about the large scale structure of the Earth and the detailed structure of its crust	• describe the properties of P waves and S waves • outline how a seismic wave's path is affected by the properties of the material it travels through • explain how seismic waves are reflected and refracted at an interface • outline the structure and function of geophones and seismometers • summarise the evidence for a liquid outer core and a solid inner core of the Earth • outline the methods of seismic reflection and refraction • discuss the uses of seismic methods in the search for oil and gas	• solve problems and analyse information to calculate the diameter of a planetary core using a distance-travel-time graph • perform an investigation to model the principles of the reflection and refraction of seismic methods • analyse information from a graph of travel time versus shot-to-geophone distance for a single layer • gather, process and present diagrammatic information to show the paths of P and S waves through the Earth
4. Studies of past and present physical phenomena indicate that the Earth is dynamic	• describe the Earth's current magnetic field • account for the evidence that the Earth's magnetic field varies over time • explain how the magnetic time scale and magnetic anomalies are used to date the age of the oceanic crust • summarise the geophysical evidence that supports the theory of plate tectonics • discuss the initial reluctance of the scientific community to accept the mobility of the Earth's plates	• perform an investigation that models, and present information to demonstrate how the inclination of the Earth's magnetic field varies with latitude • solve problems and analyse information to calculate the spreading rate of an ocean using a magnetic polarity time scale and a magnetic anomaly profile • gather secondary information to analyse the nature of heat flow and seismicity at the edges of a crustal plate
5. Geophysics provides information that is of economic and social benefit	• examine the role of geophysics in exploration using a case study • explain the benefits of geophysical methods in mineral exploration and environmental monitoring • describe the role that geophysicists have played in one of the following: – our current understanding of the age of the Earth – monitoring nuclear test ban treaties – natural hazard reduction	• identify data sources, plan, choose equipment or resources for, and perform an investigation to demonstrate the use of a geophysical method in the field • identify data sources, gather, process, analyse information and use available evidence to assess the impact of technological developments increasing an understanding of the Earth's structure and behaviour

9.6 Option — Medical Physics

Contextual Outline

The use of other advances in technology, developed from our understanding of the electromagnetic spectrum, and based on sound physical principles, has allowed medical technologists more sophisticated tools to analyse and interpret bodily process for diagnostic purposes. Diagnostic imaging expands the knowledge of practitioners and their patients and the practice of medicine. It usually uses non-invasive methods for identifying and monitoring diseases or injuries via the generation of images representing internal anatomic structures and organs of the body.

Technologies, such as ultrasound, computed axial tomography, positron emission tomography and magnetic resonance imaging, can often provide clear diagnostic pictures without surgery. A magnetic resonance image (MRI) scan of the spine, for example, provides a view of the discs in the back, as well as the nerves and other soft tissues. The practitioner can look at the MRI films and determine whether there is a pinched nerve, a degenerative disc or a tumour. The greatest advantage of these techniques are their ability to allow the practitioner to see inside the body without the need for surgery.

Outcomes

The main course outcomes to which this module contributes are:

A student:

H1 evaluates how major advances in scientific understanding and technology have changed the direction or nature of scientific thinking

H4 assesses the impact of applications of physics on society and the environment

H5 identifies possible future directions of research in physics

H8 analyses wave interactions and explains the effects of those interactions

H9 explains the effects of electric, magnetic and gravitational fields

H10 describes the nature of electromagnetic radiation and matter in terms of the particles

H11 justifies the appropriateness of a particular investigation plan

H12 evaluates ways in which accuracy and reliability could be improved in investigations

H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding

H14 assesses the validity of conclusions drawn from gathered data and information

H15 explains why an investigation is best undertaken individually or by a team

H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science.

1. The properties of ultrasound waves can be used as diagnostic tools

Students learn to:

- describe the properties and production of ultrasound and compare it to sound in normal hearing range
- describe the piezoelectric effect and the effect of using an alternating potential difference with a piezoelectric crystal
- define acoustic impedance: $Z = \rho \upsilon$ and identify that different materials have different acoustic impedances
- describe how the principles of acoustic impedance and reflection and refraction are applied to ultrasound
- identify that the ratio of reflected to initial intensity is: $$\frac{I_r}{I_o} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$$
- explain that the greater the difference in acoustic impedance between two materials the greater the reflected proportion of the incident pulse
- describe the situations in which A scans, B scans and phase and sector scans would be used and the reasons for the use of each
- describe the Doppler effect with respect to sound and how it is used in ultrasonics to obtain flow characteristics of blood flow through the heart
- outline some cardiac problems that can be detected through the use of the Doppler effect

Students:

- solve problems and analyse information to calculate the acoustic impedance of a range of materials, including bone, muscle, soft tissue, fat, blood and air and explain the types of tissues that ultrasound can be used to examine
- gather secondary information to observe at least two ultrasound images of body organs
- identify data sources and gather information to observe the flow of blood through the heart from a Doppler ultrasound video image
- identify data sources, gather, process and analyse information to describe how ultrasound is used to measure bone density
- solve problems and analyse information using: $Z = \rho \upsilon$ and $$\frac{I_r}{I_o} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$$
- identify data sources, plan, choose equipment or resources for, and perform a first-hand investigation to demonstrate the Doppler effect

	Students learn to:	*Students:*
2. The physical properties of electromagnetic radiation can be used as diagnostic tools	• describe how X-rays are currently produced • compare the differences between 'soft' and 'hard' X-rays • explain how a computed axial tomography (CAT) scan is produced • describe circumstances where a CAT scan would be a superior diagnostic tool compared to either X-rays or ultrasound • explain how an endoscope works in relation to total internal reflection • discuss differences between the role of coherent and incoherent bundles of fibres in an endoscope • explain why different types of optical fibres will affect the image produced by an endoscope • explain how an endoscope is used in: – observing internal organs – obtaining tissue samples of internal organs for further testing	• gather information to observe at least one image of a fracture on an X-ray film and X-ray images of other body parts • gather secondary information to observe a CAT scan and compare the information provided by CAT scans to that provided by X-rays • perform a first-hand investigation to observe the transfer of light by optical fibres • gather secondary information to observe internal organs from the video images produced by an endoscope
3. Radioactivity can be used as a diagnostic tool	• outline properties of radioactive isotopes and their half lives • identify radioisotopes that are used to obtain scans of organs • describe how radioactive isotopes may be metabolised by the body to bind or accumulate in the target organ • identify that during decay of specific radioactive nuclei positrons are given off • discuss the interaction of electrons and positrons resulting in the production of gamma rays • describe how positron emission tomography (PET) technique is used for diagnosis	• perform an investigation to compare a bone scan with an X-ray • gather and process secondary information to compare the scan of at least one healthy body organ with its diseased counterpart

	Students learn to:	*Students:*
4. The magnetic field produced by particles can be used as a diagnostic tool	• identify that the nuclei of certain atoms and molecules behave as small magnets • identify that protons and neutrons in the nucleus have properties of spin and describe how net spin is obtained • explain that the behaviour of nuclei with a net spin, particularly hydrogen, is related to the magnetic field they produce • describe the changes that occur in the orientation of the magnetic axis of nuclei before and after the application of a strong magnetic field • define precessing and relate the frequency of the precessing, ie Larmor frequency, to the composition of the nuclei and the strength of the applied external magnetic field • discuss the effect of subjecting precessing nuclei to pulses of radio waves • explain that the amplitude of the signal given out when precessing nuclei relax is related to the number of nuclei present • explain that large differences would occur in the relaxation time between tissue containing hydrogen bound water molecules and tissues containing other molecules	• perform an investigation to observe magnetic resonance image (MRI) scans, including a comparison of healthy and cancerous tissue • identify data sources, gather, process and present information using available evidence to explain why MRIs can be used to: – detect cancerous tissues – identify areas of high blood flow – distinguish between grey and white matter in the brain • gather and process secondary information to identify the function of the electromagnet, the radio frequency oscillator, the radio receiver and the computer in the MRI equipment • identify data sources, gather and process information to compare the advantages and disadvantages of X-rays, CAT scans, PETs and MRIs • gather, analyse information and use available evidence to assess the impact of medical applications of physics on society

9.7 Option — Astrophysics

Contextual Outline

The wonders of the universe are revealed through technological advances based on tested principles of physics. Our understanding of the cosmos draws upon models, theories and laws in our endeavour to seek explanations for the myriad of observations made at many different wavelengths. Techniques, such as imaging, photometry, astrometry and spectroscopy, allow us to determine many of the properties and characteristics of celestial objects. Continual technical advancement has resulted in a range of devices extending from optical and radio-telescopes on Earth to orbiting telescopes, such as Hipparcos, Chandra and HST.

Explanations for events in our spectacular universe, based on our understandings of the electromagnetic spectrum, allow for insights into the relationships between supernovae, star formation and evolution, and extreme events, such as high gravity environments of a neutron star or black hole.

Objects that generate high-energy radiations spanning the electromagnetic spectrum from radio to high-energy gamma rays are studied to further our understanding of nucleosynthesis, Type I and Type II supernovae and Einstein's Law of relativity.

Outcomes

The main course outcomes to which this module contributes are:

A student:

- H2 analyses the ways in which models, theories and laws in physics have been tested and validated
- H4 assesses the impact of applications of physics on society and the environment
- H7 explains the effect of energy transfers and transformation
- H8 analyses wave interactions and explains the effects of those interactions
- H9 explains the effects of electric, magnetic and gravitational fields
- H11 justifies the appropriateness of a particular investigation plan
- H12 evaluates ways in which accuracy and reliability could be improved in investigations
- H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding
- H14 assesses the validity of conclusions drawn from gathered data and information
- H15 explains why an investigation is best undertaken individually or by a team
- H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Our understanding of celestial objects depends upon observations made from Earth or space near the Earth	• recall the components of the electromagnetic spectrum and describe the properties of each component • explain why some wavebands can only be detected from space • define the terms resolution and sensitivity • discuss the problems associated with ground-based astronomy in terms of resolution and selective absorption of radiation • outline methods by which the resolution and sensitivity of ground-based systems can be improved, including: – adaptive optics – interferometry	• process information to discuss Galileo's utilisation of the telescope to identify properties of the moon • identify data sources, plan, choose equipment or resources for, and perform an investigation to demonstrate why it is desirable for telescopes to have a large diameter objective lens or mirror in terms of both sensitivity and resolution • gather, process and present information on new generation optical telescopes
2. Careful measurement of a celestial object's position, in the sky (astrometry) may be used to determine its distance	• define the terms parallax, parsec, light year • explain how trigonometric parallax can be used to determine the distance to relatively close stars • discuss the limitations with trigonometric parallax measurements • outline the results from astrometric satellites such as Hipparcos	• analyse information to calculate the distance to a star given its trigonometric parallax • gather and process information to determine the relative limits to trigonometric parallax distance determinations using ground-based and space-based methods of measurement • solve problems and analyse information using $d = 1/p$

	Students learn to:	*Students:*
3. Spectroscopy is a vital tool for astronomers and provides a wealth of information	• account for the production of emission and absorption spectra and compare these with a continuous blackbody spectrum • describe the technology needed to measure astronomical spectra • identify the general types of spectra produced by stars, emission nebulae, galaxies and quasars • describe the key features of stellar spectra and explain how these are used to classify stars • describe how spectra can provide information on surface temperature, rotational and translational velocity, density and chemical composition of stars • explain qualitatively how Stefan's Law is related to stellar radii	• process information to examine a variety of spectra produced by discharge tubes, reflected sunlight, incandescent filaments • solve problems and analyse information to calculate the surface temperature of a star from its intensity/wavelength graph • gather information about stellar spectra from either a first-hand investigation or second-hand sources and use available evidence to classify stars
4. Photometric measurements can be used for determining distance and comparing objects	• define absolute and apparent magnitude • explain how the concept of magnitude can be used to determine the distance to a celestial object • outline spectroscopic parallax • explain how two-colour values (ie colour index, B-V) are obtained and why they are useful • describe the advantages of photoelectric detectors over photographic methods for photometry	• solve problems and analyse information using: $M = m - 5\log(\frac{d}{10})$ and $\frac{I_A}{I_B} = 100^{(m_B - m_A)/5}$ to calculate the absolute or apparent magnitude of stars using photographic or digital data and a reference star • perform an investigation to demonstrate why it is important to use filters for photometry • identify data sources, gather, process and present information to assess the impact of improvements in measurement technologies on understanding of the celestial objects

	Students learn to:	*Students:*
5. The study of binary and variable stars reveals vital information about stars	• describe binary stars in terms of means of detection: visual, eclipsing, spectroscopic and astrometric • explain the importance of binary stars in determining stellar masses • classify variable stars as either intrinsic or extrinsic and periodic or non-periodic • explain the importance of the period-luminosity relationship for distance determination for cepheids	• perform an investigation to model the light curves of eclipsing binaries using computer simulation • solve problems and analyse information by applying: $m_1 + m_2 = \frac{4\pi^2 r^3}{GT^2}$
6. Stars evolve and eventually 'die'	• describe the processes involved in stellar formation • outline the key stages in a star's life in terms of the physical processes involved • describe the types of nuclear reactions involved in main-sequence and post-main sequence stars • discuss the synthesis of elements in stars • explain how the age of a cluster can be determined from its zero-age main sequence plot for a H-R diagram • explain the concept of star death in relation to: – planetary nebula – supernovae – white dwarfs – neutron stars/pulsars – black holes	• present information by plotting Hertzsprung-Russell diagrams for: nearby or brightest stars; stars in a young open cluster; stars in a globular cluster • analyse information from a H-R diagram and use available evidence to determine the characteristics of a star and its evolutionary stage • present information by plotting on a H-R diagram the pathways of stars from 0.1 to 10 solar mass during their life and relate the mass of the initial protostar to the final end point • gather, analyse information and use available evidence to assess the impact of increased knowledge in astrophysics on society

9.8 Option — From Quanta to Quarks

Contextual Outline

In the early part of the twentieth century, many experimental and theoretical problems remained unresolved. Attempts to explain the behaviour of matter on the atomic level with the laws of classical physics were not successful. Phenomena, such as black-body radiation, the photoelectric effect, the emission of sharp spectral lines by atoms in a gas discharge tube, could not be understood within the framework of classical physics.

Between 1900 and 1930, a revolution took place and a new more generalised formulation called quantum mechanics was developed. This new approach was highly successful in explaining the behaviour of atoms, molecules and nuclei. As with relativity, quantum theory requires a modification of ideas about the physical world.

Outcomes

The main course outcomes to which this module contributes are:

A student:

- H1 evaluates how major advances in scientific understanding and technology have changed the direction or nature of scientific thinking
- H2 analyses the ways in which models, theories and laws in physics have been tested and validated
- H5 identifies possible future directions of research in physics
- H6 explains events in terms of Newton's Laws, Law of Conservation of Momentum and relativity
- H7 explains the effect of energy transfers and transformations
- H8 analyses wave interactions and explains the effects of those interactions
- H9 explains the effects of electric, magnetic and gravitational fields
- H10 describes the nature of electromagnetic radiation and matter in terms of the particles
- H11 justifies the appropriateness of a particular investigation plan
- H12 evaluates ways in which accuracy and reliability could be improved in investigations
- H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding
- H14 assesses the validity of conclusions drawn from gathered data and information
- H15 explains why an investigation is best undertaken individually or by a team
- H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Problems with the Rutherford model of the atom led to the search for a model that would better explain the observed phenomena	• discuss the structure of the Rutherford model of the atom, the existence of the nucleus and electron orbits • analyse the significance of the hydrogen spectrum in the development of Bohr's model of the atom • discuss Planck's contribution to the concept of quantised energy • define Bohr's postulates • describe how Bohr's postulates led to the development of a mathematical model to account for the existence of the hydrogen spectrum: $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ • discuss the limitations of the Bohr model of the hydrogen atom	• perform a first-hand investigation to observe the hydrogen spectrum • process and present diagrammatic information to illustrate Bohr's findings with the Balmer series • solve problems and analyse information using: $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ • identify data sources, gather, process and analyse secondary information to identify the difficulties with the Rutherford-Bohr model, including its inability to completely explain: – the spectra of larger atoms – the relative intensity of spectral lines – the existence of hyperfine spectral lines – the Zeeman effect
2. The limitations of classical physics gave birth to quantum physics	• describe the impact of De Broglie's proposal that any kind of particle has both wave and particle properties • describe the confirmation of De Broglie's proposal by Davisson and Germer • explain the stability of the electron orbits in the Bohr atom using De Broglie's hypothesis	• solve problems and analyse information using: $\lambda = \frac{h}{mv}$ • gather, process, analyse and present information and use available evidence to assess the contributions made by Heisenberg and Pauli to the development of atomic theory
3. Today, quantum physics is used in a range of technologies, including electron microscopes	• outline the application of the wave characteristics of electrons in the electron microscope • discuss the relationships in electron microscopes between the electrons, magnetic lenses and refraction	• process and analyse information to compare the resolving powers of light and electron microscopes and assess the impact of their development

	Students learn to:	*Students:*
4. The work of Chadwick and Fermi in producing artificial transmutations led to practical applications of radiation	• identify the importance of conservation laws to Chadwick's discovery of the neutron • define the contents of the nucleus (protons and neutrons) as nucleons and contrast their properties • define the term 'transmutation' • describe Fermi's experimental observation of nuclear fission and his demonstration of a nuclear chain reaction • identify that Pauli's suggestion of the existence of neutrino is related to the need to account for the energy distribution of electrons emitted in ß-decay • describe nuclear transmutations due to natural radioactivity • evaluate the relative contributions of electrostatic and gravitational forces between nucleons • account for the need for the strong nuclear force and describe its properties • explain the concept of a mass defect using Einstein's equivalence between mass and energy • compare requirements for a controlled and uncontrolled nuclear chain reaction	• gather and analyse data to assess the impact of Pauli's suggestion of the neutrino on Fermi's work • identify data sources, and gather, process, and analyse information to describe the use of a specific named isotope in: – medicine – agriculture – engineering • solve problems and analyse information to calculate the mass defect and energy released in a fission reaction • analyse information and use available evidence to assess how Chadwick's and Fermi's work changed understanding of the atom

	Students learn to:	*Students:*
5. An understanding of the nucleus has led to large science projects and many applications	• explain the basic principles of a fission reactor • describe some medical and industrial applications of radio-isotopes • explain why neutron scattering is used as a probe by referring to the properties of neutrons	• gather, process and analyse information to assess the significance of the Manhattan Project to society • perform a first-hand investigation to determine the penetrating power of alpha, beta and gamma radiation on range of materials
6. Our attempts to understand the structure of matter is an ongoing process	• identify the ways by which physicists continue to develop their understanding of matter, including: – the use of accelerators as a probe to investigate the structure of matter – the key features and components of the standard model of matter, including quarks and leptons – the links between high energy particle physics and cosmology	• analyse information to assess the impact of advances in the understanding of matter on the work of physicists

9.9 Option — The Age of Silicon

Contextual Outline

The invention of the transistor by Bardeen, Brattain and Shockley paved the way for a wide range of new electronic devices. Today's technology, from computers and lasers, to jet engines and space probes, has been based on twentieth century advances in material science. Utilising a knowledge of the electrical, magnetic, optical and thermal properties of compounds of transition and rare earth metals allows for its application to robotics, automation in the manufacturing industry and advances in the personal computer industry.

Semiconducting material is the basis of the integrated circuits that run our computers and many modern technologies, including programmable controllers. Many modern technologies use electro-mechanical principles to interface real world sensors and outputs to microprocessors, temperature controllers, thermocouples and power regulators.

Outcomes

The main course outcomes to which this module contributes are:

A student:

- H3 assesses the impact of particular advances in physics on the development of technologies
- H4 assesses the impact of applications of physics on society and the environment
- H7 explains the effect of energy transfers and transformation
- H11 justifies the appropriateness of a particular investigation plan
- H12 evaluates ways in which accuracy and reliability could be improved in investigations
- H13 uses terminology and reporting styles appropriately and successfully to communicate information and understanding
- H14 assesses the validity of conclusions drawn from gathered data and information
- H15 explains why an investigation is best undertaken individually or by a team
- H16 justifies positive values about and attitudes towards both the living and non-living components of the environment, ethical behaviour and a desire for critical evaluation of the consequences of the applications of science.

	Students learn to:	*Students:*
1. Electronics has undergone rapid development due to greater knowledge of the properties of materials and increasingly complex manufacturing techniques	• identify that early computers each employed hundreds of thousands of single transistors • explain that the invention of the integrated circuit using a silicon chip was related to the need to develop lightweight computers and compact guidance systems • explain the impact of the development of the silicon chip on the development of electronics • outline the similarities and differences between an integrated circuit and a transistor	• identify data sources, gather, process and analyse information to outline the rapid development of electronics and, using examples, relate this to the impact of electronics on society • gather secondary information to identify the desirable optical properties of silicon, including: – refractive index – ability to form fibres – optical non-linearity
2. Electronics use analogue and digital systems, the basic circuit elements of which are potential dividers and transistors	• describe the difference between an electronic circuit and an electric circuit and the advantages and disadvantages of each • distinguish between digital and analogue systems in terms of their ability to respond to or process continuous or discrete information • identify systems that are digital and ones that are analogue in a range of devices • identify potential dividers and transducers as common elements in both analogue and digital systems • explain how the ratio of resistances in a potential divider allows a range of voltages to be obtained • describe the role of transducers as an interface between the environment and an electronic system	• identify data sources, perform an investigation to demonstrate the difference between digital and analogue voltage outputs over time • gather, process and present information to identify electronic systems that use analogue systems, including television and radio sets and those that use digital systems, including CD players • solve problems and analyse information involving resistances, voltages and currents in potential dividers

	Students learn to:	*Students:*
3. Sensors and other devices allow the input of information in electronic systems	• define a transducer as a device that can be affected by or affect the environment • explain the relationship in a light-dependent resistor (LDR) between resistance and the amount of light falling on it • describe the role of LDRs in cameras • explain why thermistors are transducers and describe the relationship between temperature and resistance in different types of thermistors • distinguish between positive and negative temperature coefficient thermistors • explain the function of thermistors in fire alarms and thermostats that control temperature	• gather, process and present graphically information on the relationship between resistance and the amount of light falling on a light-dependent resistor • solve problems and analyse information involving circuit diagrams of LDRs and thermistors • gather and analyse information and use available evidence to explain why solar cells, switches and the light meter in a camera may be considered input transducers
4. Some devices use output transducers to make connections between the product and the environment	• explain the need for a relay when a large current is used in a device • describe the role of the electromagnet, pivot, switch contacts and insulator in a relay • describe the structure of light-emitting diodes (LEDs) in terms of p-type and n-type semiconductors • explain why voltmeters, ammeters, CROs and other electronic meters are considered output transducers	• process information to explain the way in which a relay works using a circuit diagram • solve problems and analyse information using circuit diagrams involving LEDs and relays • analyse information to assess situations where an LED would be preferable to an ordinary light source

	Students learn to:	*Students:*
5. Information can be processed using electronic circuits	• describe the behaviour of the logic gates in terms of the high and low voltages and relate these to input and outputs • identify that gates can be used in combination with each other to make half or full adders	• identify data sources, plan, choose equipment or resources for, and perform first-hand investigations to construct truth tables for logic gates • solve problems and analyse information using circuit diagrams involving logic gates
6. Amplifiers are used in different ways in current technologies	• describe the functions and the properties of an ideal amplifier • identify the voltage over which the amplifier acts as a linear or analogue device and a digital device • describe how amplifier can be used as amplifying circuits • explain that the gain of an amplifier is related to the ratio of its output voltage to its input voltage: $\frac{V_{out}}{V_{in}}$ • define open loop gain: $A_O = \frac{V_O}{(v_+ - v_-)}$ • explain the difference between the non-inverting input and the inverting input • discuss how a control system can be used to provide feedback	• solve problems and analyse information to show the transfer characteristics of an amplifier • gather and present graphical information to distinguish between the input and output voltages when the voltages are applied to the inverting and non-inverting inputs respectively • solve problems and analyse information using: $\frac{V_{out}}{V_{in}}$ and $A_O = \frac{V_O}{(v_+ - v_-)}$ • gather information to identify the different ways in which amplifiers are used in current technologies
7. There are physics limits that may impact on the future uses of computers	• identify that the increased speed of computers has been accompanied by a decrease in size of circuit elements • explain that as circuit component size is decreasing, quantum effects become increasingly important	• gather, process and analyse information and use available evidence to discuss the possibility that there may be a limit on the growth of computer power and this may require a reconceptualisation of the way computers are designed

10 Course Requirements

For the Preliminary course:

- 120 indicative hours are required to complete the course
- the content in each module must be addressed over the course
- experience over the course must cover the scope of each skill as described in Section 8.1
- practical experiences should occupy a minimum of 45 indicative hours of course time
- at least one open-ended investigation integrating the skills and knowledge and understanding outcomes is required.

For the HSC course:

- the Preliminary course is a prerequisite
- 120 indicative hours are required to complete the course
- the content in each module of the core and one elective must be addressed over the course
- experiences over the course must cover the scope of each skill as described in Section 9.1
- practical experiences should occupy a minimum of 35 indicative hours of course time
- at least one open-ended investigation integrating the skills and knowledge and understanding outcomes is required.

11 Post-school Opportunities

The study of Physics Stage 6 provides students with knowledge, understanding and skills that form a valuable foundation for a range of courses at university and other tertiary institutions.

In addition, the study of Physics Stage 6 assists students to prepare for employment and full and active participation as citizens. In particular, there are opportunities for students to gain recognition in vocational education and training. Teachers and students should be aware of these opportunities.

Recognition of Student Achievement in Vocational Education and Training (VET)

Wherever appropriate, the skills and knowledge acquired by students in their study of HSC courses should be recognised by industry and training organisations. Recognition of student achievement means that students who have satisfactorily completed HSC courses will not be required to repeat their learning in courses in TAFE NSW or other Registered Training Organisations (RTOs).

Registered Training Organisations, such as TAFE NSW, provide industry training and issue qualifications within the Australian Qualifications Framework (AQF).

The degree of recognition available to students in each subject is based on the similarity of outcomes between HSC courses and industry training packages endorsed within the AQF. Training packages are documents that link an industry's competency standards to AQF qualifications. More information about industry training packages can be found on the National Training Information Service (NTIS) website (www.ntis.gov.au).

Recognition by TAFE NSW

TAFE NSW conducts courses in a wide range of industry areas, as outlined each year in the *TAFE NSW Handbook*. Under current arrangements, the recognition available to students of Physics in relevant courses conducted by TAFE is described in the *HSC/TAFE Credit Transfer Guide*. This guide is produced by the Board of Studies and TAFE NSW and is distributed annually to all schools and colleges. Teachers should refer to this guide and be aware of the recognition available to their students through the study of Physics Stage 6. This information can be found on the TAFE NSW website (www.tafensw.edu.au/mchoice).

Recognition by other Registered Training Organisations

Students may also negotiate recognition into a training package qualification with another RTO. Each student will need to provide the RTO with evidence of satisfactory achievement in Physics Stage 6 so that the degree of recognition available can be determined.

12 Assessment and Reporting

12.1 Requirements and Advice

The information in this section of the syllabus relates to the Board of Studies' requirements for assessing and reporting achievement in the Preliminary and HSC courses for the Higher School Certificate.

Assessment is the process of gathering information and making judgements about student achievement for a variety of purposes.

In the Preliminary and HSC courses those purposes include:

- assisting student learning
- evaluating and improving teaching and learning programs
- providing evidence of satisfactory achievement and completion in the Preliminary course
- providing the Higher School Certificate results.

Reporting refers to the Higher School Certificate documents received by students that are used by the Board to report both the internal and external measures of achievement.

NSW Higher School Certificate results will be based on:

- an **assessment mark** submitted by the school and produced in accordance with the Board's requirements for the internal assessment program
- an **examination mark** derived from the HSC external examinations.

Results will be reported using a course report containing a performance scale with bands describing standards of achievement in the course.

The use of both internal assessment and external examinations of student achievement allows measures and observations to be made at several points and in different ways throughout the HSC course. Taken together, the external examinations and internal assessment marks provide a valid and reliable assessment of the achievement of the knowledge, understanding and skills described for each course.

Standards Referencing and the HSC Examination

The Board of Studies will adopt a standards-referenced approach to assessing and reporting student achievement in the Higher School Certificate examination.

The standards in the HSC are:

- the knowledge, skills and understanding expected to be learned by students — the *syllabus standards*
- the levels of achievement of the knowledge, skills and understanding — the *performance standards.*

Both *syllabus standards* and *performance standards* are based on the aims, objectives, outcomes and content of course. Together they specify what is to be learned and how well it is to be achieved.

Teacher understanding of standards comes from the set of aims, objectives, outcomes and content in each syllabus together with:

- the performance description the summarise the different levels of performance of the course outcomes
- HSC examination papers and marking guidelines
- samples of students' achievement on assessment and examination task.

12.2 Internal Assessment

The internal assessment mark submitted by the school will provide a summation of each student's achievements measured at points throughout the course. It should reflect the rank order of students and relative differences between students' achievements.

Internal assessment provides a measure of a student's achievement based on a wider range of syllabus content and outcomes than may be covered by the external examination alone.

The assessment components, weightings and task requirements to be applied to internal assessment are identified on page 89. They ensure a common focus for internal assessment in the course across schools, while allowing for flexibility in the design of tasks. A variety of tasks should be used to give students the opportunity to demonstrate outcomes in different ways and to improve the validity and reliability of the assessment.

12.3 External Examination

In Physics Stage 6, the external examinations include written papers for external marking. The specifications for the examination in Physics Stage 6 are on page 90.

The external examination provides a measure of student achievement in a range of syllabus outcomes that can be reliably measured in an examination setting.

The external examination and its marking and reporting will relate to syllabus standards by:

- providing clear links to syllabus outcomes
- enabling students to demonstrate the levels of achievement outlined in the course performance scale
- applying marking guidelines based on established criteria.

12.4 Board Requirements for the Internal Assessment Mark In Board Developed Courses

For each course, the Board requires schools to submit an assessment mark for each candidate.

The collection of information for the HSC internal assessment mark must not begin prior to the completion of the Preliminary course.

The Board requires that the assessment tasks used to determine the internal assessment mark must comply with the components, weightings and types of tasks specified in the table on page 89.

Schools are required to develop an internal assessment program that:

- specifies the various assessment tasks and the weightings allocated to each task
- provides a schedule of the tasks designed for the whole course.

The school must also develop and implement procedures to:

- inform students in writing of the assessment requirements for each course before the commencement of the HSC course
- ensure that students are given adequate written notice of the nature and timing of assessment tasks
- provide meaningful feedback on each student's performance in all assessment tasks.
- maintain records of marks awarded to each student for all assessment tasks
- address issues relating to illness, misadventure and malpractice in assessment tasks
- address issues relating to late submission and non-completion of assessment tasks
- advise students in writing if they are not meeting the assessment requirements in a course and indicate what is necessary to enable the students to satisfy the requirements
- inform students about their entitlements to school reviews and appeals to the Board
- conduct school reviews of assessments when requested by students
- ensure that students are aware that they can collect their Rank Order Advice at the end of the external examinations at their school.

12.5 Assessment Components, Weightings and Tasks

Preliminary Course

The suggested components, weightings and tasks for the Preliminary course are detailed below.

Component	Weighting	Tasks may include:
The World Communicates	25	*assignments* *fieldwork studies and reports* *model making*
Electrical Energy in the Home	25	*open-ended investigations* *oral reports* *practical tests*
Moving About	25	*reports* *research projects*
The Cosmic Engine	25	*topic tests and examination* Tasks to assess students' abilities to conduct first-hand investigations and communicate information and understanding based on these investigations should be included.
Marks	**100**	

There should be a balance between the assessment of:

- knowledge and understanding outcomes and course content;
- skills outcomes and course content.

HSC Course

The internal assessment mark for Physics Stage 6 is to be based on the HSC course only. Final assessment should be based on a range and balance of assessment instruments.

Component	Weighting	Tasks may include:
Space Motor and Generators From Ideas to Implementation Option	25 25 25 25	*assignments* *fieldwork studies and reports* *model making* *open-ended investigations* *oral reports* *practical tests* *reports* *research projects* *topic tests and examination* **Note:** No more than 50% weighting may be allocated to examinations and topic tests, A minimum of 30% weighting must be allocated to tasks that assess students' abilities to conduct first-hand investigations and communicate information and understanding based on these investigations.
Marks	**100**	

There should be a balance between the assessment of:

- knowledge and understanding outcomes and course content;
- skills outcomes and content.

One task may be used to assess several components. It is suggested that 3–5 tasks are sufficient to assess the HSC course outcomes.

12.6 HSC External Examination Specifications

The written examination in Physics will consist of one examination paper of 3 hours duration (plus 5 minutes reading time). A formulae sheet will be supplied. The examination paper will consist of TWO sections:

Section I: Core (75 marks)

Part A (15 marks)

- There will be FIFTEEN multiple-choice questions.
- All questions will be compulsory.
- All questions will be of equal value.
- Questions will be based on the HSC core modules.

Part B (60 marks)

- Short-answer and extended response questions.
- Marks for individual questions will be shown on the examination paper.
- All questions will be compulsory.
- Questions will be based on the HSC core modules.

Section II: Options (25 marks)

- There will be FIVE questions: one on each of the FIVE HSC options. Each question may consist of several parts.
- Marks for individual parts will be shown on the examination paper.
- Candidates must attempt ONE question.
- All questions will be of equal value.

HSC options list

- Geophysics
- Medical Physics
- Astrophysics
- From Quanta to Quarks
- The Age of Silicon.

12.7 Summary of Internal and External Assessment

Internal Assessment	Weighting	External Assessment	Weighting
		A written examination paper consisting of:	
Core Modules	75	Core Modules *Multiple-choice questions* *Short-answer questions* *Longer answer question/s*	75
Option *Note: Assessment of knowledge, understanding, and skills developed through conducting first-hand investigations should be incorporated into the Core and Option as appropriate.*	25	Options *Short-answer questions* *Longer answer question/s*	25
Marks	**100**	**Marks**	**100**

12.8 Reporting Student Performance Against Standards

Student performance in an HSC course will be reported against standards on a course report. The course report contains a performance scale for the course describing levels (bands) of achievement, an HSC examination mark and the internal assessment mark. It will also show, graphically, the statewide distribution of examination marks of all students in the course.

Each band on the performance scale (except for band 1), includes descriptions that summarise the attainments typically demonstrated in that band.

The distribution of marks will be determined by students' performances against the standards and not scaled to a predetermined pattern of marks.