



Physics

Stage 6 Syllabus

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Contents

1	The Higher School Certificate Program of Study	4
2	Rationale for Physics in the Stage 6 Curriculum	5
3	Continuum of Learning for Physics Stage 6 Students	6
4	Aim.....	7
5	Objectives.....	7
6	Course Structure.....	8
6.1	Preliminary Course	8
6.2	HSC Course	9
6.3	Overview	10
6.4	Other Considerations	13
7	Objectives and Outcomes.....	14
7.1	Table of Objectives and Outcomes.....	14
7.2	Key Competencies.....	16
8	Content: Physics Stage 6 Preliminary Course.....	17
8.1	Physics Skills.....	17
8.2	The World Communicates.....	20
8.3	Electrical Energy in the Home.....	25
8.4	Moving About.....	29
8.5	The Cosmic Engine	34
9	Content: Physics Stage 6 HSC Course.....	37
9.1	Physics Skills.....	37
9.2	Space.....	40
9.3	Motors and Generators	44
9.4	From Ideas to Implementation.....	48
9.5	Option – Geophysics	53
9.6	Option – Medical Physics.....	57
9.7	Option – Astrophysics	61
9.8	Option – From Quanta to Quarks	65
9.9	Option – The Age of Silicon.....	69
10	Course Requirements	74
11	Post-school Opportunities	75
12	Assessment and Reporting	76
13	Appendix.....	77

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.

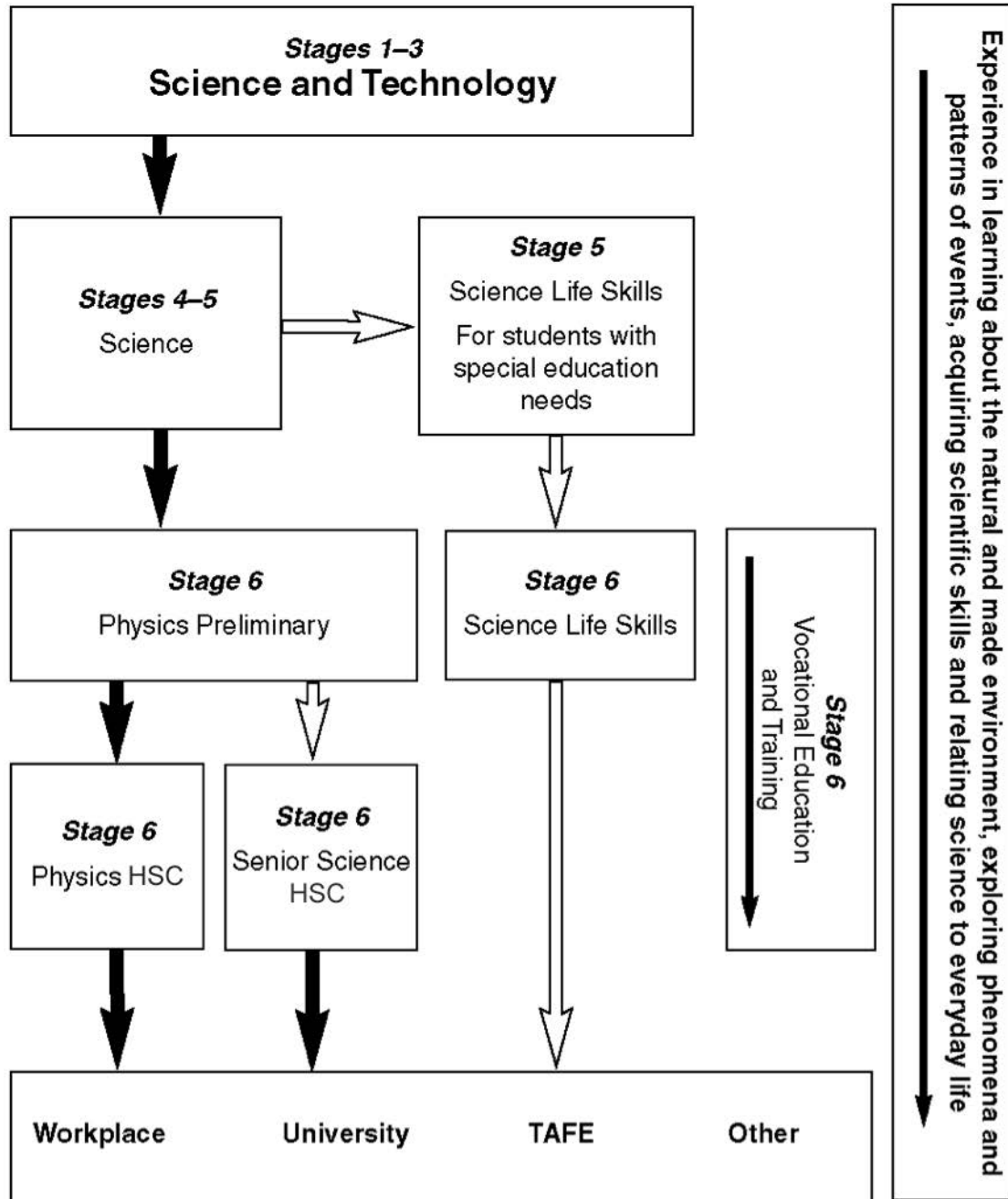
The study of physics relies on the understanding and application of a small number of basic laws and principles that govern the microscopic and macroscopic worlds. The study of physics provides students with an understanding of systems that is the basis of the development of technological applications. 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:

The core, which includes:

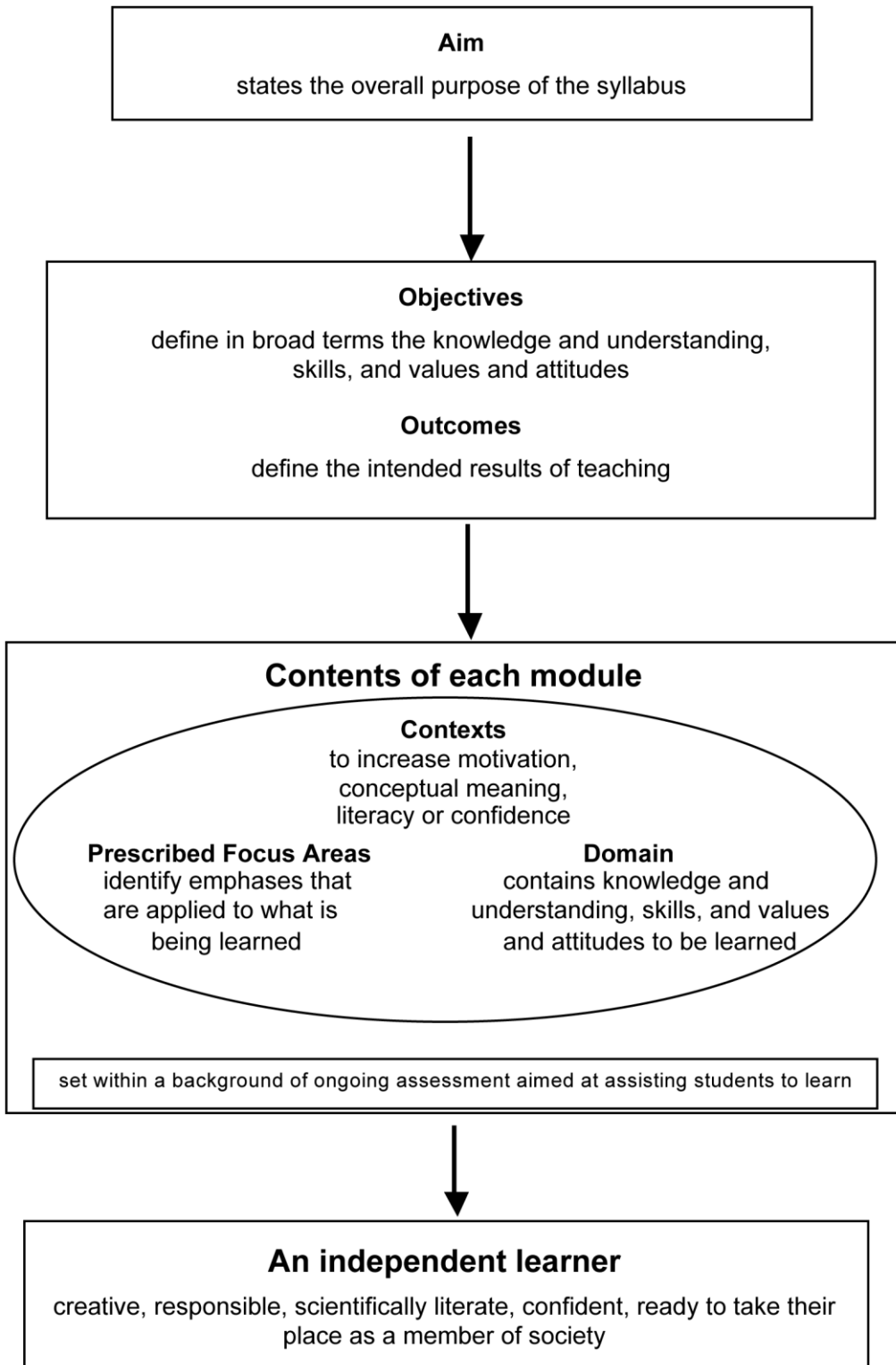
- Space (30 indicative hours)
- Motors and Generators (30 indicative hours)
- From Ideas to Implementation (30 indicative hours)

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:



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 *Work Health and Safety Act 2011* (NSW) and the *Work Health and Safety Regulations 2011* (NSW), as well as system and school requirements in relation to safety when implementing their programs.

Schools should refer to the resource package *Chemical Safety in Schools* (DET, 1999) to assist them in meeting their legislative obligations.

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	<i>Students will develop knowledge and understanding of:</i>	<i>A student:</i>	<i>A student:</i>
	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 for society and the environment	P4. describes applications of physics which affect society or the environment	H4. assesses the impacts 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 research in physics	H5. identifies possible future directions of physics research
Domain: Knowledge	6. kinematics and dynamics	P6. describes the forces acting on an object which causes 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 effects of energy transfers and energy transformations
	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

Physics Stage 6 Syllabus

	Objectives	Preliminary Course Outcomes	HSC Course Outcomes
	<i>Students will develop knowledge and understanding of:</i>	<i>A student:</i>	<i>A student:</i>
Domain: Skills	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 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 & Attitudes	16. themselves, others, learning as a lifelong process, physics and the environment	P16. demonstrates positive values about, and attitude 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 attitude 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
<p><i>A student:</i> P11. identifies and implements improvements to investigation plans</p>	<p><i>Students:</i></p> <p>11.1 identify data sources to:</p> <ul style="list-style-type: none"> 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 <p>11.2 plan first-hand investigations to:</p> <ul style="list-style-type: none"> 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 <p>11.3 choose equipment or resources by:</p> <ul style="list-style-type: none"> 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
<p><i>A student:</i> P12. discusses the validity and reliability of data gathered from first-hand investigations and secondary sources</p>	<p><i>Students:</i> 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</p>
	<p>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</p>
	<p>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</p>
	<p>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</p>

Preliminary Course Outcomes	Content
<p><i>A student:</i> P13. identifies appropriate terminology and reporting styles to communicate information and understanding in physics</p>	<p><i>Students:</i> 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</p>
<p>P14. draws valid conclusions from gathered data and information</p>	<p>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</p> <p>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</p> <p>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</p>
<p>P15. implements strategies to work effectively as an individual or as a member of a team</p>	<p>The Preliminary course further increases students' skills in working individually and in teams. Refer to the content overview on page 14.</p>

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 distances with improved accuracy of information transfer. A messenger was required to carry the information in hard copy form and this carrier 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 carrier of 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.

This module increases students' understanding of the nature, practice, application and uses of physics and current issues, research and developments in physics.

Assumed Knowledge

Domain: knowledge and understanding:

Refer to the *Science Years 7–10 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 and refraction 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
- 5.12a) describe some everyday uses and effects of electromagnetic radiation, including applications in communication technology.

1. The wave model can be used to explain how current technologies transfer information

Students learn to:

- describe the energy transformations required in one of the following:
 - mobile telephone
 - fax/modem
 - radio and television
- 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
- identify 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:

$$v = f\lambda$$

Students:

- perform a first-hand investigation to observe and gather information about the transmission of waves in:
 - slinky springs
 - water surfaces
 - ropesor use appropriate computer simulations
- present diagrammatic information about transverse and longitudinal waves, direction of particle movement and the direction of propagation
- perform a first-hand investigation to gather information about the frequency and amplitude 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 the frequency and wavelength of a sound 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

2. Features of a wave model can be used to account for the properties of sound

Students learn to:

- identify that sound waves are vibrations or oscillations of particles in a medium
- relate compressions and rarefactions of sound waves to the crests and troughs of transverse waves used to represent them
- 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 principle of superposition and compare the resulting waves to the original waves in sound

Students:

- perform a first-hand investigation and gather information to analyse sound waves from a variety of sources using the Cathode Ray Oscilloscope (CRO) or an alternate computer technology
- 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 the electromagnetic spectrum

Students learn to:

- describe electromagnetic waves in terms of their speed in space and their lack of requirement of a medium for propagation
- identify the electromagnetic wavebands filtered out by the atmosphere, especially UV, X-rays and gamma rays
- identify methods for the detection of various wavebands in the electromagnetic spectrum
- explain that the relationship between the intensity of electromagnetic radiation and distance from a source 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 problems produced by the limited range of the electromagnetic spectrum available for communication purposes

Students:

- 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
- analyse information to identify the waves involved in the transfer of energy that occurs during the use of one of the following:
 - mobile phone
 - television
 - radar
- analyse information to identify the electromagnetic spectrum range utilised in modern communication technologies

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

Students learn to:

- describe and apply the law of reflection and explain the effect of reflection from a plane surface on waves
- 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 being reflected by the ionosphere
- explain that refraction is related to the velocities of a wave in different media and outline how this may result in the bending of a wavefront
- define refractive index in terms of changes in the velocity of a wave in passing from one medium to another
- define Snell's Law:

$$\frac{v_1}{v_2} = \frac{\sin i}{\sin r}$$

- identify the conditions necessary for total internal reflection with reference to the critical angle
- outline how total internal reflection is used in optical fibres

5. 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

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
 - 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 calculate the refractive index of glass or perspex
 - solve problems and analyse information using Snell's Law
-
- 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
 - CD technology
 - the internet (digital process)
 - DVD technology

8.3 Electrical Energy in the Home

Contextual Outline

Electricity is an essential energy source for modern living. Disruption to supply or isolation can lead to the development of alternative methods of obtaining this essential energy resource. For electrical energy to be useful it must be harnessed through the use of an electrical circuit and an energy-converting appliance.

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 became 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.

This module increases students' understanding of the history, nature and practice of physics and the applications and uses of physics.

Assumed Knowledge

Domain: knowledge and understanding:

Refer to the *Science Years 7–10 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 the characteristics and applications of series and parallel circuits.

	<i>Students learn to:</i>	<i>Students:</i>
1. Society has become increasingly dependent on electricity over the last 200 years	<ul style="list-style-type: none">▪ 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 energy for a community▪ discuss some of the ways in which electricity can be provided in remote locations	<ul style="list-style-type: none">▪ identify data sources, gather, process and analyse secondary information about the differing views of Volta and Galvani about animal and chemical electricity and discuss whether their different views contributed to increased understanding of electricity

2. One of the main advantages of electricity is that it can be moved with comparative ease from one place to another through electric circuits

Students learn to:

- describe the behaviour of electrostatic charges and the properties of the fields associated with them
- define the unit of electric charge as the coulomb
- define the electric field as a field of force with a field strength equal to the force per unit charge at that point:

$$E = \frac{F}{q}$$

- 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 electric 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 changes between different points around a DC circuit
- identify the difference between conductors and insulators
- define resistance as the ratio of voltage to current for a particular conductor:

$$R = \frac{V}{I}$$

- describe qualitatively how each of the following affects the movement of electricity through a conductor:
 - length
 - cross sectional area
 - temperature
 - material

Students:

- present diagrammatic information to describe the electric field strength and direction:
 - between charged parallel plates
 - about and between a positive and negative point charge
- solve problems and analyse information using:

$$E = \frac{F}{q}$$

- plan, choose equipment for and perform a first-hand investigation to gather data and use the available evidence to show the relationship between voltage across and current in a DC circuit
- 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 DC circuit
- gather and process secondary information to identify materials that are commonly used as conductors to provide household electricity

	<i>Students learn to:</i>	<i>Students:</i>
3. Series and parallel circuits serve different purposes in households	<ul style="list-style-type: none">▪ identify the difference between series and parallel circuits▪ compare parallel and series circuits in terms of voltage across components and current through them▪ identify uses of ammeters and voltmeters▪ 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	<ul style="list-style-type: none">▪ 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▪ plan, choose equipment or resources and perform a first-hand investigation to construct simple model household circuits using electrical components
4. The amount of power is related to the rate at which energy is transformed	<ul style="list-style-type: none">▪ explain that power is the rate at which energy is transformed from one form to another▪ identify the relationship between power, potential difference and current▪ identify that the total amount of energy used depends on the length of time the current is flowing and can be calculated using: $\text{Energy} = VI t$▪ explain why the kilowatt-hour is used to measure electrical energy consumption rather than the joule	<ul style="list-style-type: none">▪ perform a first-hand investigation, gather information and use available evidence to demonstrate the relationship between current, voltage and power for a model 6V to 12V electric heating coil▪ solve problems and analyse information using: $P = VI$and $\text{Energy} = VI t$

Students learn to:

5. Electric currents also produce magnetic fields and these fields are used in different devices in the home

- describe the behaviour of the magnetic poles of bar magnets 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 north magnetic pole when placed at that point
- describe the magnetic field around 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

6. Safety devices are important in household circuits

- discuss the dangers of an electric shock from both a 240 volt AC mains supply and various DC voltages, from appliances, on the muscles of the body
- describe the functions of circuit breakers, fuses, earthing, double insulation and other safety devices in the home

Students:

- plan, choose equipment or resources for, and perform a first-hand investigation to build an electromagnet
- perform a first-hand investigation to observe magnetic fields by mapping lines of force:
 - around a bar magnet
 - surrounding a straight DC current-carrying conductor
 - a solenoid
 - present information using \otimes and \odot to show the direction of a current and direction of a magnetic field
- identify data sources, gather, process and analyse information to explain one application of magnetic fields in household appliances

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, time 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 the vehicle, even at low or moderate speeds.

The faster a vehicle is travelling, the further it will go before it is able to stop when subject to a constant retarding force. Major damage can be done to other vehicles and to the human body in collisions, 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.

This module increases students' understanding of the nature and practice of physics and the implications of physics for society and the environment.

Assumed Knowledge

Domain: knowledge and understanding:

Refer to the *Science Years 7–10 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.

1. Vehicles do not typically travel at a constant speed

Students learn to:

- identify that a typical journey involves speed changes
- distinguish between the instantaneous and average speed of vehicles and other bodies
- distinguish between scalar and vector quantities in equations
- compare instantaneous and average speed with instantaneous and average velocity
- define average velocity as:

$$v_{av} = \frac{\Delta r}{\Delta t}$$

Students:

- plan, choose equipment or resources for, and perform a first-hand investigation to measure the average speed of an object or a vehicle
- solve problems and analyse information using the formula:

$$v_{av} = \frac{\Delta r}{\Delta t}$$

where r = displacement

- present information graphically of:
 - displacement vs time
 - velocity vs timefor objects with uniform and non-uniform linear velocity

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

Students learn to:

- describe the motion of one body relative to another
- identify the usefulness of using vector diagrams to assist solving problems
- 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
- describe 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:

- analyse the 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
- solve problems using vector diagrams to determine resultant velocity, acceleration and force
- plan, choose equipment or resources 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

- solve problems and analyse information involving

$$F = \frac{mv^2}{r}$$

for vehicles travelling around curves

<p>3. Moving vehicles have kinetic energy and energy transformations are an important aspect in understanding motion</p>	<p><i>Students learn to:</i></p> <ul style="list-style-type: none"> ▪ identify that a moving object possesses kinetic energy and that work done on that object can increase that energy ▪ describe the energy transformations that occur in collisions ▪ define the law of conservation of energy 	<p><i>Students:</i></p> <ul style="list-style-type: none"> ▪ solve problems and analyse information to determine the kinetic energy of a vehicle and the work done using the formulae: $E_k = \frac{1}{2}mv^2$ <p>and</p> $W = Fs$
<p>4. Change of momentum relates to the forces acting on the vehicle or the driver</p>	<p><i>Students learn to:</i></p> <ul style="list-style-type: none"> ▪ define momentum as: $p = mv$ <ul style="list-style-type: none"> ▪ define impulse as the product of force and time ▪ explain why momentum is conserved in collisions in terms of Newton's Third Law of motion 	<ul style="list-style-type: none"> ▪ analyse information to trace the energy transfers and transformation in collisions leading to irreversible distortions ▪ solve problems and analyse secondary data using: $p = mv$ <p>and</p> $\text{impulse} = Ft$ <ul style="list-style-type: none"> ▪ 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: <ul style="list-style-type: none"> – a stationary vehicle – an immovable object – another vehicle moving in the opposite direction – another vehicle moving in the same direction

5. Safety devices are utilised to reduce the effects of changing momentum

Students learn to:

- define the inertia of a vehicle as its tendency to remain in uniform motion or at rest
- discuss reasons why Newton's First Law of Motion is not apparent in many real world situations
- assess the reasons for the introduction of low speed zones in built-up areas and the addition of air bags and crumple zones to vehicles with respect to the concepts of impulse and momentum
- evaluate the effectiveness of some safety features of motor vehicles

Students:

- gather and process first-hand data and/or secondary information to analyse the potential danger presented by loose objects in a vehicle
- 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

8.5 The Cosmic Engine

Contextual Outline

The Universe began with a singularity in space-time. After the initial explosion, the Universe started to expand, cool and condense, forming matter. As part of this ongoing process the Sun and the Solar System were formed over 4×10^9 years ago from a gas cloud which resulted from a supernova explosion. The condensing gas and dust that formed the Sun and the planets contained all its original elements. The planets were formed when matter came together under the influence of gravity.

This module increases students' understanding of the history of physics, implications of physics for society and the environment and current issues, research and developments in physics.

Assumed Knowledge

Domain: knowledge and understanding:

Refer to the *Science Years 7–10 Syllabus* for the following:

- 5.6.5a) identify that energy and particles 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.

Students learn to:

1. Our Sun 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 the time of Aristotle to the time of Newton

Students:

- identify data sources, and gather, process and analyse information to assess one of the models of the Universe developed from the time of Aristotle to the time of Newton to identify limitations placed on the development of the model by the technology available at the time

- | | | |
|---|--|---|
| | <i>Students learn to:</i> | <i>Students:</i> |
| 2. The first minutes of the Universe released energy which changed to matter, forming stars and galaxies | <ul style="list-style-type: none">▪ outline the discovery of the expansion of the Universe by Hubble, following its earlier prediction by Friedmann▪ describe 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:<ul style="list-style-type: none">– expansion and cooling of the Universe– subsequent loss of particle kinetic energy– gravitational attraction between particles– lumpiness of the gas cloud that then allows gravitational collapse | <ul style="list-style-type: none">▪ identify data sources and gather secondary information to describe the probable origins of the Universe |
| 3. Stars have a limited life span and may explode to form supernovas | <ul style="list-style-type: none">▪ define the relationship between the temperature of a body and the dominant wavelength of the radiation emitted from that body▪ identify 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 surface temperature▪ identify energy sources characteristic of each star group, including Main Sequence, red giants, and white dwarfs | <ul style="list-style-type: none">▪ gather secondary information to relate brightness of an object to its luminosity and distance▪ solve problems to apply the inverse square law of intensity of light to relate the brightness of a star to its luminosity and distance from the observer▪ process and analyse information using the Hertzsprung-Russell diagram to examine the variety of star groups, including Main Sequence, red giants, and white dwarfs |

4. The Sun is a typical star, emitting electromagnetic radiation and particles that influence the Earth

Students learn to:

- 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 and beta β particles and gamma γ rays in terms of:
 - ionising power
 - penetrating power
 - effect of magnetic field
 - effect of electric field
- identify the nature of emissions reaching the Earth from the Sun
- describe the particulate nature of the solar wind
- 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

Students:

- perform a first-hand investigation to gather information to compare the penetrating power of alpha, beta and gamma radiation in a range of materials
- 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 satellite communications

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
<i>A student:</i> H11. justifies the appropriateness of a particular investigation plan	<i>Students:</i> 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
<p><i>A student:</i> H12. evaluates ways in which accuracy and reliability could be improved in investigations</p>	<p><i>Students:</i> 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</p>
	<p>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</p>
	<p>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 information about their research</p>
	<p>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</p>

HSC Course Outcomes	Content
<p><i>A student:</i> H13. uses terminology reporting styles appropriately and successfully to communicate information and understanding</p>	<p><i>Students:</i> 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</p>
<p>H14. assesses the validity of conclusions drawn from gathered data and information</p>	<p>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</p> <p>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</p> <p>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</p>
<p>H15. explains why an investigation is best undertaken individually or by a team</p>	<p>The HSC course builds on the Preliminary course and further increases the students' skills in working individually and in teams. Refer to the content overview on page 14.</p>

9.2 Space

Contextual Outline

Scientists have drawn on advances in areas such as aeronautics, material 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. 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 fifty 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 from research undertaken in space programs has impacted on society through the development of devices such as personal computers, advanced medical equipment and communication satellites, and has enabled the accurate mapping of natural resources. Space research and exploration increases our understanding of the Earth's own environment, the Solar System and the Universe.

This module increases students' understanding of the history, nature and practice of physics and the implications of physics for society and the environment.

	<i>Students learn to:</i>	<i>Students:</i>
<p>1. The Earth has a gravitational field that exerts a force on objects both on it and around it</p>	<ul style="list-style-type: none"> ▪ define weight as the force on an object due to a gravitational field ▪ explain that a change in gravitational potential energy is related to work done ▪ 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 $E_p = -G \frac{m_1 m_2}{r}$	<ul style="list-style-type: none"> ▪ perform an investigation and gather information to determine a value for acceleration due to gravity using pendulum motion or computer-assisted technology and identify reason for possible variations from the value 9.8 ms^{-2} ▪ gather secondary information to predict 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 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
- outline Newton's concept of escape velocity
- identify why the term 'g forces' is used to explain the forces acting on an astronaut during launch
- discuss the effect 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 low Earth and geo-stationary orbits
- define the term orbital velocity and the quantitative and qualitative relationship between orbital velocity, the gravitational constant, mass of the central body, mass of the satellite and the radius of the orbit using Kepler's Law of Periods
- account for the orbital decay of satellites in low Earth orbit

Students:

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

$$v_x^2 = u_x^2$$

$$v = u + at$$

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

$$\Delta x = u_x t$$

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

- perform a first-hand investigation, gather information and analyse data to calculate initial and final velocity, maximum height reached, range and time of flight of a projectile for a range of situations by using simulations, data loggers and computer analysis
- identify data sources, gather, analyse and present information on the contribution of one of the following to the development of space exploration: Tsiolkovsky, Oberth, Goddard, Esnault-Pelterie, O'Neill or von Braun
- solve problems and analyse information to calculate the centripetal force acting on a satellite undergoing uniform circular motion about the Earth using:

$$F = \frac{mv^2}{r}$$

- solve problems and analyse information using:

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

Students learn to:

- 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 safe re-entry for a manned spacecraft into the Earth's atmosphere and the consequences of failing to achieve this angle

3. The Solar System is held together by gravity

- describe a gravitational field in the region surrounding a massive object in terms of its effects on other masses in it
- define Newton's Law of Universal Gravitation:

$$F = G \frac{m_1 m_2}{d^2}$$

- discuss the importance of Newton's Law of Universal Gravitation in understanding and calculating the motion of satellites
- identify that a slingshot effect can be provided by planets for space probes

Students:

- present information and use available evidence to discuss the factors affecting the strength of the gravitational force
- solve problems and analyse information using:

$$F = G \frac{m_1 m_2}{d^2}$$

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 the Michelson-Morley experiments in making determinations about competing theories
- outline the nature of inertial frames of reference
- discuss the principle of relativity
- describe the significance of Einstein's assumption of the constancy of the speed of light
- identify that if c is constant then space and time become relative
- discuss the concept that length standards are defined in terms of time in contrast to the original metre standard
- 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
 - mass dilation
- discuss the implications of mass increase, time dilation and length contraction for space travel

Students:

- gather and process information to interpret the results of 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:

$$E = mc^2$$

$$l_v = l_0 \sqrt{1 - \frac{v^2}{c^2}}$$

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

$$m_v = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

9.3 Motors and Generators

Contextual Outline

Modern industrialised 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 but 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.

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 electrical power requires relative motion between a magnetic field and a conductor. In a generator, mechanical energy is converted into electrical energy while the opposite occurs in an electric motor.

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.

This module increases students' understanding of the applications and uses of physics and the implications of physics for society and the environment.

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

Students learn to:

- 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 between 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 that the motor effect is due to the force acting on a current-carrying conductor in a magnetic field
- describe the forces experienced by a current-carrying loop in a magnetic field and describe the net result of the forces
- describe the main features of a DC electric motor and the role of each feature
- identify that the required magnetic fields in DC motors can be produced either by current-carrying coils or permanent magnets

Students:

- solve problems using:

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

- 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:

$$F = BIl \sin \theta$$

- solve problems and analyse information about simple motors using:

$$\tau = nBIA \cos \theta$$

- identify data sources, gather and process information to qualitatively describe the application of the motor effect in:
 - the galvanometer
 - the loudspeaker

	<i>Students learn to:</i>	<i>Students:</i>
2. The relative motion between a conductor and magnetic field is used to generate an electrical voltage	<ul style="list-style-type: none">▪ 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▪ describe the concept of magnetic flux in terms of magnetic flux density and surface area▪ describe 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▪ explain the production of eddy currents in terms of Lenz's Law	<ul style="list-style-type: none">▪ 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 the effect on a generated electric current when:<ul style="list-style-type: none">– 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 induction is used in cooktops in electric ranges▪ gather secondary information to identify how eddy currents have been utilised in electromagnetic braking
3. Generators are used to provide large scale power production	<ul style="list-style-type: none">▪ describe the main components of a generator▪ compare the structure and function of a generator to an electric motor▪ describe the differences between AC and DC generators▪ discuss the energy losses that occur as energy is fed through transmission lines from the generator to the consumer▪ assess the effects of the development of AC generators on society and the environment	<ul style="list-style-type: none">▪ plan, choose equipment or resources for, and perform a first-hand investigation to demonstrate the production of an alternating current▪ gather secondary information to discuss advantages/disadvantages of AC and DC generators and relate these to their use▪ analyse secondary information on the competition between Westinghouse and Edison to supply electricity to cities▪ gather and analyse information to identify how transmission lines are:<ul style="list-style-type: none">– insulated from supporting structures– protected from lightning strikes

4. Transformers allow generated voltage to be either increased or decreased before it is used

Students learn to:

- describe the purpose of transformers in electrical circuits
- compare step-up and step-down transformers
- identify 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
- discuss the impact of the development of transformers on society

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

Students:

- 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 secondary information to discuss the need for transformers in the transfer of electrical energy from a power station to its point of use
-
- perform an investigation to demonstrate the principle of an AC induction motor
 - 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 and diffraction, and 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.

This module increases students' understanding of the history, nature and practice of physics and the applications and uses of physics, the implications of physics for society and the environment, and the current issues, research and developments in physics.

1. Increased understandings of cathode rays led to the development of television

Students learn to:

- explain why the apparent inconsistent behaviour of cathode rays caused debate as to whether they were charged particles or electromagnetic waves
- explain that cathode ray tubes allowed the manipulation of a stream of charged particles
- identify that moving charged particles in a magnetic field experience a force
- 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 of:
 - electrodes in the electron gun
 - the deflection plates or coils the fluorescent screen
 in the cathode ray tube of conventional TV displays and oscilloscopes

Students:

- 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 to demonstrate and identify properties of cathode rays using discharge tubes:
 - containing a maltese cross
 - containing electric plates
 - with a fluorescent display screen
 - containing a glass wheel
 - analyse the information gathered to determine the sign of the charge on cathode rays
- solve problem and analyse information using:

$$F = qvB\sin\theta$$

$$F = qE$$

and

$$E = \frac{V}{d}$$

2. The reconceptualisation of the model of light led to an understanding of the photoelectric effect and black body radiation

Students learn to:

- 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 qualitatively Hertz's experiments in measuring the speed of radio waves and how they relate to light waves
- identify Planck's hypothesis that radiation emitted and absorbed by the walls of a black body cavity is quantised
- identify Einstein's contribution to quantum theory 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

$$c = f\lambda$$

Students:

- perform an investigation to demonstrate the production and reception of radio waves
- identify data sources, gather, process and analyse information and use available evidence to assess Einstein's contribution to quantum theory and its relation to black body radiation
- identify data sources, gather, process and present information to summarise the use of the photoelectric effect in photocells
- solve problems and analyse information using:

$$E = hf$$

and

$$c = f\lambda$$

- process information to discuss Einstein's and Planck's differing views about whether science research is removed from social and political forces

3. Limitations of past technologies and increased research into the structure of the atom resulted in the invention of transistors

Students learn to:

- 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
- 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
- describe differences between solid state and thermionic devices and discuss why solid state devices replaced thermionic devices

Students:

- perform an investigation to model 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 communication technology lead to an increased knowledge of the properties of materials with particular reference to the invention of the transistor
- 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
- identify data sources, gather, process and present information to summarise the effect of light on semiconductors in solar cells

4. Investigations into the electrical properties of particular metals at different temperatures led to the identification of superconductivity and the exploration of possible applications

Students learn to:

- outline the methods used by the Braggs to determine crystal structure
- identify that metals possess a crystal lattice structure
- describe conduction in metals as a free movement of electrons unimpeded by the lattice
- identify that resistance in metals is increased by the presence of impurities and scattering of electrons by lattice vibrations
- describe the occurrence in superconductors below their critical temperature of a population of electron pairs unaffected by electrical resistance
- discuss the BCS theory
- discuss the advantages of using superconductors and identify limitations to their use

Students:

- process information to identify some of the metals, metal alloys and compounds that have been identified as exhibiting the property of superconductivity and their critical temperatures
- perform an investigation to demonstrate magnetic levitation
- analyse information 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 a maglev train
- 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

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 for 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 its material properties, geophysicists explore the Earth in ways that human senses cannot.

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

This module increases students’ understanding of the history of physics and the implications of physics for society and the environment.

1. Geophysics involves the measurement of physical properties of the Earth	<i>Students learn to:</i>	<i>Students:</i>
	<ul style="list-style-type: none"> ▪ 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, gravitational, magnetic, palaeomagnetic, electrical, electromagnetic, radiometric and geothermal, and describe the type of information that two of these methods can provide 	<ul style="list-style-type: none"> ▪ identify data sources, gather and process information to discuss Newton’s proposal for the shape of the Earth using data gathered from investigations involving 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

2. Some physical phenomena such as gravitation and radiation provide information about the Earth at a distance from it

Students learn to:

- describe how absorption and reflection of radiation can provide information about a reflecting surface
- explain how remote sensing techniques can be used to monitor climate, vegetation and pollution
- identify two uses of remote sensing of radiation in mineral exploration
- outline reasons why the gravitational field of the Earth varies at different points on its surface
- describe how the paths of satellites are used to study the Earth's gravity
- outline the structure and function of a gravimeter
- describe the purpose of data reduction in gravity surveys
- recount the steps involved in gravity data reduction including latitude correction, free air correction and Bouguer correction
- identify and describe the uses of gravity methods in resource exploration

Students:

- 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
- solve problems and analyse information to calculate the mass of the Earth, given the period and the altitude of a satellite:
$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$
- process information from secondary sources to reduce collected gravity data

	<i>Students learn to:</i>	<i>Students:</i>
3. Seismic methods provide information about the large scale structure of the Earth and the detailed structure of its crust	<ul style="list-style-type: none">▪ 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	<ul style="list-style-type: none">▪ perform an investigation to model the principles of the reflection and refraction of seismic waves▪ 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	<ul style="list-style-type: none">▪ describe the Earth's current magnetic field▪ account for the evidence that the Earth's magnetic field varies over time▪ summarise the geophysical evidence that supports the theory of plate tectonics▪ discuss the initial reluctance of some of the scientific community to accept the mobility of the Earth's plates in the absence of a mechanism for plate movement	<ul style="list-style-type: none">▪ 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

5. Geophysics provides information that is of economic and social benefit

Students learn to:

- explain the benefits of geophysical methods in mineral exploration and environmental monitoring
- describe the role that geophysicists have played in the following:
 - monitoring nuclear test ban treaties
 - natural hazard reduction

Students:

- identify data sources, plan, choose equipment or resources for, and perform an investigation to demonstrate the use of a geophysical method in the field

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 the practice of medicine. It usually uses non-invasive methods for identifying and monitoring diseases or injuries via the generation of images representing internal anatomical structures and organs of the body.

Technologies, such as ultrasound, compute 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.

This module increases students' understanding of the history of physics and the implications of physics for society and the environment.

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

Students learn to:

- identify the differences between ultrasound and 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:

$$Z = \rho v$$
 and identify that different materials have different acoustic impedances
- describe how the principles of acoustic impedance and reflection and refraction are applied to ultrasound
- define the ratio of reflected to initial intensity as:

$$\frac{I_r}{I_0} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$$
- identify that the greater the difference in acoustic impedance between two materials, the greater is the reflected proportion of the incident pulse
- describe situations in which A scans, B scans and sector scans would be used and the reasons for the use of each
- describe the Doppler effect in sound waves and how it is used in ultrasonics to obtain flow characteristics of blood moving 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:

$$Z = \rho v$$

and

$$\frac{I_r}{I_0} = \frac{[Z_2 - Z_1]^2}{[Z_2 + Z_1]^2}$$

2. The physical properties of electromagnetic radiation can be used as diagnostic tools

Students learn to:

- 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 how an endoscope is used in:
 - observing internal organs
 - obtaining tissue samples of internal organs for further testing

3. Radioactivity can be used as a diagnostic tool

- outline properties of radioactive isotopes and their half lives 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 the positron emission tomography (PET) technique is used for diagnosis

Students:

- 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 image and compare the information provided by CAT scans to that provided by an X-ray image for the same body part
- perform a first-hand investigation to demonstrate the transfer of light by optical fibres
- gather secondary information to observe internal organs from images produced by an endoscope
- perform an investigation to compare an image of bone scan with an X-ray image
- gather and process secondary information to compare a scanned image of at least one healthy body part or organ with a scanned image of its diseased counterpart

4. The magnetic field produced by nuclear particles can be used as a diagnostic tool

Students learn to:

- 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 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

Students:

- perform an investigation to observe images from magnetic resonance image (MRI) scans, including a comparison of healthy and damaged tissue
- identify data sources, gather, process and present information using available evidence to explain why MRI scans 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, radio frequency oscillator, radio receiver and computer in the MRI equipment
- identify data sources, gather and process information to compare the advantages and disadvantages of X-rays, CAT scans, PET scans and MRI scans
- 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 by various instruments 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 star formation and evolution (supernovae), and extreme events, such as high gravity environments of a neutron star or black hole.

This module increases students' understanding of the nature and practice of physics and the implications of physics for society and the environment.

	<i>Students learn to:</i>	<i>Students:</i>
<p>1. Our understanding of celestial objects depends upon observations made from Earth or from space near the Earth</p>	<ul style="list-style-type: none"> ▪ discuss Galileo's use of the telescope to identify features of the Moon ▪ discuss why some wavebands can be more easily detected from space ▪ define the terms 'resolution' and 'sensitivity' of telescopes ▪ discuss the problems associated with ground-based astronomy in terms of resolution and absorption of radiation and atmospheric distortion ▪ outline methods by which the resolution and/or sensitivity of ground-based systems can be improved, including: <ul style="list-style-type: none"> – adaptive optics – interferometry – active optics 	<ul style="list-style-type: none"> ▪ 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

2. Careful measurement of a celestial object's position in the sky (astrometry) may be used to determine its distance

Students learn to:

- define the terms parallax, parsec, light-year
- explain how trigonometric parallax can be used to determine the distance to stars
- discuss the limitations of trigonometric parallax measurements

Students:

- solve problems and analyse information to calculate the distance to a star given its trigonometric parallax using:

$$d = \frac{1}{p}$$

- gather and process information to determine the relative limits to trigonometric parallax distance determinations using recent ground-based and space-based telescopes
- perform a first-hand investigation to examine a variety of spectra produced by discharge tubes, reflected sunlight, or incandescent filaments
- analyse information to predict the surface temperature of a star from its intensity/wavelength graph

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 describe 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

4. Photometric measurements can be used for determining distance and comparing objects

Students learn to:

- 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 (eg colour index, B-V) are obtained and why they are useful
- describe the advantages of photoelectric technologies over photographic methods for photometry

Students:

- solve problems and analyse information using:

$$M = m - 5 \log\left(\frac{d}{10}\right)$$

and

$$\frac{I_A}{I_B} = 100^{(m_B - m_A)/5}$$

to calculate the absolute or apparent magnitude of stars using data and a reference star

- perform an investigation to demonstrate the use of filters for photometric measurements
- identify data sources, gather, process and present information to assess the impact of improvements in measurement technologies on our understanding of celestial objects
- perform an investigation to model the light curves of eclipsing binaries using computer simulation
- solve problems and analyse information by applying:

$$m_1 + m_2 = \frac{4\pi^2 r^3}{GT^2}$$

5. The study of binary and variable stars reveals vital information about stars

- describe binary stars in terms of the means of their 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 determining the distance of cepheids

6. Stars evolve and eventually ‘die’

Students learn to:

- 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 by fusion
- explain how the age of a globular 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

Students:

- 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 of 1, 5 and 10 solar masses during their life cycle

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 and 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.

This module increases students' understanding of the history, nature and practice of physics and the current issues, research and developments in physics.

	<i>Students learn to:</i>	<i>Students:</i>
<p>1. Problems with the Rutherford model of the atom led to the search for a model that would better explain the observed phenomena</p>	<ul style="list-style-type: none"> ▪ 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 ▪ define Bohr's postulates ▪ discuss Planck's contribution to the concept of quantised energy ▪ 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 	<ul style="list-style-type: none"> ▪ perform a first-hand investigation to observe the visible components of the hydrogen spectrum ▪ process and present diagrammatic information to illustrate Bohr's explanation of the Balmer series ▪ solve problems and analyse information using: $\frac{1}{\lambda} = R \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$ ▪ analyse secondary information to identify the difficulties with the Rutherford-Bohr model, including its inability to completely explain: <ul style="list-style-type: none"> – 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

Students learn to:

- describe the impact of de Broglie's proposal that any kind of particle has both wave and particle properties
- define diffraction and identify that interference occurs between waves that have been diffracted
- 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

Students:

- 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. The work of Chadwick and Fermi in producing artificial transmutations led to practical applications of nuclear physics

Students learn to:

- define the components of the nucleus (protons and neutrons) as nucleons and contrast their properties
- discuss the importance of conservation laws to Chadwick's discovery of the neutron
- define the term 'transmutation'
- describe nuclear transmutations due to natural radioactivity
- describe Fermi's initial experimental observation of nuclear fission
- discuss Pauli's suggestion of the existence of neutrino and relate it to the need to account for the energy distribution of electrons emitted in β -decay
- 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
- describe Fermi's demonstration of a controlled nuclear chain reaction in 1942
- compare requirements for controlled and uncontrolled nuclear chain reactions

Students:

- perform a first-hand investigation or gather secondary information to observe radiation emitted from a nucleus using Wilson Cloud Chamber or similar detection device
- solve problems and analyse information to calculate the mass defect and energy released in natural transmutation and fission reactions

4. An understanding of the nucleus has led to large science projects and many applications

Students learn to:

- explain the basic principles of a fission reactor
- describe some medical and industrial applications of radio-isotopes
- describe how neutron scattering is used as a probe by referring to the properties of neutrons
- identify ways by which physicists continue to develop their understanding of matter, using accelerators as a probe to investigate the structure of matter
- discuss the key features and components of the standard model of matter, including quarks and leptons

Students:

- gather, process and analyse information to assess the significance of the Manhattan Project to society
- identify data sources, and gather, process, and analyse information to describe the use of:
 - a named isotope in medicine
 - a named isotope in agriculture
 - a named isotope in engineering

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. A knowledge of the electrical, magnetic, optical and thermal properties of compounds of transition and rare earth metals enables their 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.

This module increases students' understanding of the applications and uses of physics, the implications of physics for society and the environment, and current issues, research and developments in physics.

	<i>Students learn to:</i>	<i>Students:</i>
<p>1. Electronics has undergone rapid development due to greater knowledge of the properties of materials and increasingly complex manufacturing techniques</p>	<ul style="list-style-type: none"> ▪ 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 	<ul style="list-style-type: none"> ▪ 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 silica, including: <ul style="list-style-type: none"> – refractive index – ability to form fibres – optical non-linearity

	<i>Students learn to:</i>	<i>Students:</i>
2. Electronics use analogue and digital systems, the basic circuit elements of which are potential dividers and transistors	<ul style="list-style-type: none">▪ 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 systems 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	<ul style="list-style-type: none">▪ identify and analyse data and 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
3. Sensors and other devices allow the input of information in electronic systems	<ul style="list-style-type: none">▪ 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	<ul style="list-style-type: none">▪ 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

Students learn to:

4. Some devices use output transducers to make connections between the device 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

5. Information can be processed using electronic circuits

- describe the behaviour of AND, OR and inverter logic gates in terms of 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

Students:

- 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

- 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

Students learn to:

- describe the functions and the properties of an ideal amplifier
- explain that the gain of an ideal amplifier is the ratio of its output voltage to its input voltage:

$$A_0 = \frac{V_{out}}{V_{in}}$$

- identify that an operational amplifier is a component of a typical amplifier
- describe the characteristics of an operational amplifier
- distinguish between open-loop gain and closed-loop gain
- identify the voltage range over which an operational amplifier circuit acts as a linear device
- describe how an operational amplifier can be used as an inverting amplifier
- explain that the gain of an inverting amplifier is given by:

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

- explain the difference between the non-inverting input and the inverting input
- discuss how feedback can be used in a control system
- explain the use of two input resistors to produce a summing amplifier

Students:

- solve problems and analyse information to show the transfer characteristics of an amplifier
- gather and present graphical information to show the transfer characteristics of an inverting amplifier
- solve problems and analyse information about setting the gain of an inverting amplifier by calculating the values of external resistors using:

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

- perform a first-hand investigation of a summing amplifier by adding voltages from two separate sources
- 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

Students learn to:

- 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

Students:

- 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 \(NTIS\)](http://www.ntis.gov.au) 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 [HSC/TAFE Credit Transfer](http://www.det.nsw.edu.au/hsctafe) website (www.det.nsw.edu.au/hsctafe).

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

Advice on appropriate assessment practice in relation to the Physics syllabus is contained in *Assessment and Reporting in Physics Stage 6*. That document provides general advice on assessment in Stage 6 as well as the specific requirements for the Preliminary and HSC courses. The document contains:

- suggested components and weightings for the internal assessment of the Preliminary course
- mandatory components and weightings for the internal assessment of the HSC course
- the HSC examination specifications, which describe the format of the external HSC examination.

The document and other resources and advice related to assessment in Stage 6 Physics are available on the [Board's website](http://www.boardofstudies.nsw.edu.au/syllabus_hsc) (www.boardofstudies.nsw.edu.au/syllabus_hsc).

13 Appendix

The following information clarifies terminology used in this syllabus

Optical Fibre Consisting of a core where light rays travel and the cladding which is made of a similar material with a slightly lower refractive index to cause total internal reflection. Two types of material are used to manufacture fibres – glass (silica) and plastic.