PHYSICS

SYLLABUS
for the
SENIOR
EXTERNAL
EXAMINATION

2000
(Amended 2003)

QUEENSLAND
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PREFACE

This syllabus for the Senior Physics external examination represents an evolution of the 1990 syllabus. It aligns closely with the 1995 syllabus in Physics studied by full-time students in schools.

This occasioned the adoption of the common set of headings for both general objectives and exit criteria currently used in senior science syllabuses. These are:

- knowledge of subject matter
- scientific processes
- complex reasoning processes.

Candidates will be assessed by means of two examinations, and details of these are provided in section 8. Direct assessment of the recommended practical work stated in the syllabus is not feasible, so it will be assessed indirectly in the examination papers. Consequently, there will be questions assessing candidates' knowledge of and ability to combine the practical work, the safety considerations and the use of relevant equipment in both familiar and unfamiliar situations.

The change that will have the greatest impact on the course and its assessment will be the new general objectives with their increased emphasis on scientific processes and complex reasoning processes.

1. A VIEW OF SCIENCE AND SCIENCE EDUCATION

Science is a social and cultural activity through which explanations of natural phenomena are generated. It incorporates ways of thinking that are both creative and critical. Scientists have a deep conviction that the universe is understandable.

Explanations of natural phenomena may be viewed as mental constructions based on personal experiences. They result from a range of activities that may include observation, experimentation, imagination and discussion, and are achieved by considering the complexities of the universe at a level that can be understood. The evolution of scientific understandings has been episodic, with chance sometimes playing an important role.

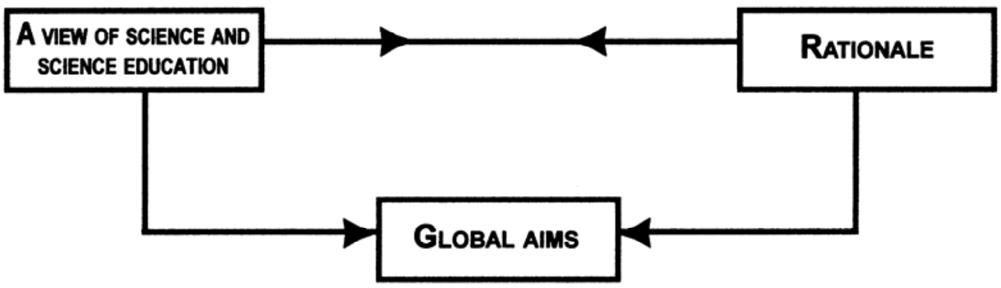
Currently, accepted scientific concepts, theories and models may be viewed as shared understandings which the scientific community perceive as viable in light of the available evidence and arguments presented and that have a predictive value. Scientific understandings are subject to questioning by the scientific community, and may be challenged and modified or replaced. Indeed this is a defining characteristic of science.

Students construct personal explanations of phenomena they experience in everyday life. One role of science education is to help students move from their personal constructions, which are often discordant with scientific explanations, towards theories and models accepted by the scientific community. As students progress through their formal education, explanations of phenomena they encounter increase in complexity, as does the level of sophistication of their observations.

Science students are encouraged to appreciate the social and cultural perspectives of science. They also participate in activities that assist them to construct explanations and recognise the nature of scientific understandings.

Through science education students are encouraged to develop critical and creative thinking skills as well as scientific understandings. This will empower them to envisage alternative outcomes and make informed decisions about science and its applications. Such decisions will influence the well-being of themselves, other living things and their environment.

The interrelationships of a view of science and science education, the subject rationale and global aims are presented in the following flowchart.



2. RATIONALE

It has always been a part of the human condition to marvel at the world we live in—stars and rainbows, the apple that falls to the ground, or the lodestone that always points north—and to ask why the world should be that way. In Western culture, this way of speculating about the world became known as natural philosophy and later, as biology and chemistry took recognisably different paths, as physics. At the same time as this separation into distinct sciences was occurring, physics developed its own methods and procedures, valuing precise measurement and highly reproducible experiments, and developing a powerful and fruitful partnership with mathematics.

It is also part of the human condition to use knowledge to gain control. Knowledge of physics has led to developments in technology, some of which, like electrical appliances and telecommunications, have had a profound impact on social structures.

The social effects of such technology may be positive or negative and, as has been the case in nuclear science, the use to which the knowledge is put may itself direct the course which physics takes.

There are hardly any aspects of modern life unaffected by science and by physics in particular. The application of scientific findings is also indirectly responsible for generating much of the material and intellectual wealth, and for providing most of the employment that preserves our way of life. For this reason, science has often been called power knowledge.

Some developments in physics, such as the Copernican revolution, Galileo's confrontation with the Church, and challenges to the accepted ideas about predictability from quantum mechanics, have influenced the course of history and philosophy. Through various levels of interaction, such developments have helped shape society's collective consciousness. Aspects of the theory of relativity, for example, have passed into modern folklore.

For all these reasons, a knowledge of physics is useful in exercising our responsibilities as citizens, in confronting technologies, understanding the relationships between the physical and social environment, pursuing hobbies and appreciating the challenge of a particular way of knowing the world.

Thus, two basic reasons emerge for the study of physics at secondary level: firstly, it is the study of some of our attempts to understand the universe and secondly, its applications have produced and continue to produce pressures to change our society. Most candidates who complete a senior physics course will gain the satisfaction of a deeper understanding of our changing world, and a few will work in physics or related areas like engineering.

3. GLOBAL AIMS

Candidates come from varied geographical, socioeconomic, sociocultural backgrounds, and language backgrounds other than English. Their background legitimately and significantly influences the nature of learning for themselves and others.

A study of a senior science should provide an opportunity for and assistance in the further development of students' abilities to access, process, evaluate and communicate information, so that they might be culturally and scientifically informed and aware. To achieve these global aims, senior Physics should provide learning experiences which will assist candidates to develop:

- the ability to recall specific knowledge and apply this in simple situations
- scientific processes, complex reasoning processes
- helpful attitudes and values
- proficiency and safety in the use of laboratory equipment and other resources
- English language and physics-specific language skills through immersion in the language of physics.

The global aims are expressed via the general objectives and developed by the specific objectives.

4. GENERAL OBJECTIVES

The general objectives of this syllabus in Physics are derived from the interaction of a view of science and science education, the rationale, and the global aims. These general objectives are described in terms of what a candidate should gain from undertaking this course of study. The candidate should:

- develop attitudes and values
- have knowledge of subject matter
- be able to use scientific processes
- be able to use complex reasoning processes
- develop manipulative skills.

Although candidates will not be assessed on attitudes and values, nor directly on manipulative skills, the other three general objectives form the broad categories under which the candidates will be assessed.

In order to explain the meaning of the **general objectives** for candidates, more detailed **objectives** have been identified. These more detailed objectives are further elaborated by means of dot-pointed **outcomes** which contain examples.

Whilst the general objectives, the more detailed objectives and the dot-pointed outcomes are descriptions of mandatory aspects in this syllabus, the examples are provided to further explain the outcomes and thus assist the candidate to develop an understanding of how the outcomes may be achieved. It is not envisaged that candidates would necessarily engage with every example, but primarily with those most relevant to their own learning context.

Specific objectives are provided in the subject matter topics.

As a result of undertaking a course of study based upon this syllabus, a candidate should:

Have opportunities to develop attitudes and values

Note: These **attitudes and values** are not directly assessable in the external examination.

Objective	Outcomes
To develop attitudes and values	• concerning the impact and limitations of science (be concerned for wise application of science and its ethical use). • arising from the practice of science (be open-minded, critically respectful for data, be sceptical, willing to shift in the face of evidence, systematic, persistent in the practice of science) • concerning personal behaviour (be honest, concerned, tolerant and aware of individual differences and cultural diversity within the learning environment), be cooperative when participating in group tasks) • …

Have a knowledge of subject matter

Note: This general objective refers to the development and assessment of content and its simple application.

Objectives	Outcomes
To recall To apply in simple situations	• list, define, state, describe, select, identify, recognise, translate, reconstruct, calculate, deduce, explain, solve, exemplify, spell correctly: – facts and formulae – procedures – terminology – theories and principles – sequences and events – shapes, patterns and diagrams – …

Be able to use scientific processes

Note: This general objective refers to the development and assessment of scientific processes at a simple level only.

Objectives	Outcomes
To collect and organise data	• use primary data resources: – observe accurately, being aware of the need to repeat and check observations – select appropriate measuring devices – use scales and units accurately, being aware of limitations and errors – describe properties and changes – …
	• use secondary data sources: – locate and comprehend relevant information from books, audiovisual and multimedia sources, databases and other resources – record references – …
	• record and organise data: – collect both qualitative and quantitative data and use standard units paying attention to accuracy and precision – classify objects by relevant properties – record observations – tabulate – graph – sketch, draw, photograph – …
To make simple judgments	• reflect on the validity of qualitative and/or quantitative data: – distinguish fact from opinion – distinguish relevant from irrelevant information – distinguish observations from inferences – identify errors in measurement – …

Continued overleaf

Objectives	Outcomes
To process and generate information	• infer and predict: – explain observations and forecast observations based on past observations or theory – …
	• interpret: – identify trends or anomalies – interpolate and extrapolate – analyse – generate analogies – follow procedures – draw conclusions – …
	• generalise: – relate cause and effect – describe relationships (qualitatively and/or quantitatively) – …
To communicate information in various contexts	• present information in a variety of forms: – write reports of laboratory or field work – present results of library research – deliver oral reports on research or experiments – contribute to discussions/debates – produce pictorial, graphical and audiovisual presentations – construct physical representations – use correct spelling, grammar and punctuation – …
To devise and design simple and/or single step investigations	• use scientific methodology: – identify/articulate investigation question(s) – identify and control variables – develop experimental procedures – establish a conceptual framework – hypothesise – identify safety issues – …

Be able to use complex reasoning processes

Note: This general objective refers to the development and assessment of higher order cognitive processes which provide challenge to candidates.

Objectives	Outcomes
To use complex reasoning in challenging situations	• solve challenging problems: – assemble several pieces of learned information and procedures and integrate them to complete a task – combine several of the scientific processes into a coherent strategy for a given task – respond to challenging novel tasks – …
	• make logical decisions: – select relevant knowledge and/or data and a procedure to reach a conclusion or support an argument – analyse alternative information to compare and contrast or make judgments – make inferences or predictions consistent with a set of assumptions – justify an outcome based on given or generated information – …
	• use creative and/or critical thinking: – identify assumptions on which claims are based – locate logical fallacies in arguments – recognise invalid conclusions – evaluate the work of ideas and the authority on which claims are based – critically examine the adequacy of data – demonstrate originality in design, production, performance – propose alternative theories for given evidence – propose evidence that would be required to confirm or refute a particular theory or belief – …
In addition to the outcomes identified above, other complex reasoning processes outcomes may involve an advanced level challenge from the knowledge of subject matter or scientific processes general objectives listing.	

5. LEARNING EXPERIENCES

The range of learning experiences provided for candidates should promote the attainment of the general objectives of the subject.

For study in Physics to contribute to a general education in science, it should provide learning experiences that will contribute to the development of individuals who:

- can identify sources of relevant information and/or data
- are aware of, and are skilled in using, scientific methods for extracting and/or collecting information or data
- can manipulate data and information in ways appropriate to the task
- make decisions based upon the best available information.

The effective use of language (written, spoken and symbolic) is integral to all of these functions. Science uses a rich spectrum of metaphors and similes to describe and communicate models that seek to explain natural phenomena. There is a general language of science, and each of the historical disciplines has its own arcane language and mental/verbal metaphors. Learning experiences should develop awareness and understanding of this language. This allows development of the successful use of scientific language and imagery.

Candidates could be engaged in learning experiences which involve them in:

Drawing upon sources of information, such as:	Using language for the purposes of:	Presenting information in forms such as:
existing knowledge	restating information	laboratory notes
observations	formulating a hypothesis	formal reports
experiments	designing an experiment	letters
textbooks	explaining a relationship	abstracts
handbooks of data	proposing action	précis
manuals of procedures	evaluating an argument	reviews
specification sheets	interpreting a theory	oral presentations
journal articles	making conclusions	seminars
magazines	predicting the results of an experiment	discussions
newspapers	evaluating scientific arguments	demonstrations
advertisements		charts
videos or films		graphs
lectures		sketches
interviews		models
discussions		photographs
Internet		electronic media
…		…

Choices of teaching and learning modes should be made to suit the needs of candidates. The suggestions that follow are neither prescriptive nor exhaustive:

- collaborative learning
- laboratory activities and experiments
- model construction
- simulation games
- teacher exposition and questioning
- film, video and slide audiovisual observation
- computer software simulation or tutorial use
- computer interfacing
- Internet/websites
- …

6. ORGANISATION

6.1 Suggested time allocations

The seven mandatory topics, with suggested percentage time allocations, are given in the following table. Suggested minimum time allocation necessary to gain a basic understanding of the topics is 100 plus hours. To consolidate these understandings, candidates will need to spend a significant amount of additional time on processing and interpreting information relevant to the topics.

	Syllabus topic	Suggested allocation %
1	Physical Quantities and Measurement	5
2	Forces and Motion	15
3	Energy and Momentum	15
4	Wave Motion and Optics	15
5	Electricity and Electronics	20
6	Magnetism and Electromagnetism	20
7	Atomic and Nuclear Physics	10
	TOTAL	100%

Each topic has two parts:

- an introduction and overview of the subject matter. These describe the context for the scientific, historical, social and practical applications of each topic. Broad connections with other core topics, as well as other scientific disciplines, are suggested
- specific objectives categorised under the headings of knowledge, scientific processes and complex reasoning processes. For further clarity, these have been grouped for the various subtopics.

All knowledge, scientific processes and complex reasoning processes objectives listed in this syllabus must be incorporated.

6.2 Resources

The selection of resource material to support a course in Physics will be governed by local factors. Although candidates will rely heavily on a textbook of Physics they must realise that any one text will not fully support the realisation of the process objectives (scientific processes and complex reasoning processes). Several textbooks which may be useful as resources are listed in appendix I.

General community resources such as museums, science centres, popular science periodicals, electronic media materials, the Internet and particular television science programs may need to be consulted.

6.3 Safety

Candidates should have a knowledge of the safe operation of all laboratory equipment used and the operation of laboratory safety equipment including:

- fire extinguishers
- fire blankets
- electrical isolation
- gas isolation
- eye-baths
- safety showers
- protection from ionising radiation.

7. SUBJECT MATTER TOPICS

Topic 1—Physical quantities and measurement

Arguably the most significant aspect of the work of Galileo, Descartes and Newton in regard to the emergence of 'natural philosophy' or physics involved the manipulation and modelling of quantitative data by mathematical and graphical techniques. To appreciate fully the elegance of the explanatory and predictive power of physics, it is essential for candidates to be confident in the use of quantitative terms and reliable data within a fundamental framework of the concepts of space and time.

The consistent use of SI (Système International d'Unités) units and scientific notation in dealing with data should pervade all aspects of the subject. In fact, the names of the physical units often provide useful thematic links, not only to indicate the historical contexts of science, but also to illuminate the unified nature of physical knowledge. The material in this topic necessarily permeates all other topics.

Learning experiences

It is not the intention of the syllabus that this topic should be taught as some kind of introduction to physics or as a self-contained topic. The material should be developed and redefined *as it is required in the context of the subsequent units,* particularly when this involves experimental processes and practical work. This is not to say that specific lessons on, for example, significant figures have no place, or that candidates will not need extensive consolidation and practice opportunities. On the contrary, it is the consistent and frequent exposure to the rigorous nature of scientific measurement and its system of units which helps to establish the particular nature of physics.

The learning situations which the candidates may experience might include:
- teacher exposition
- problem-solving activities
- accessing information from a variety of sources (including library research)
- discussion, consolidation and practice
- experimental processes and practical work
- constructing models (theoretical and concrete)
- manipulation of computer databases
- graphical techniques and computer-generated graphs
- analysis of raw data from experimental situations and computer simulations.

Specific objectives—Topic 1: Physical quantities and measurement

Knowledge of subject matter

1. List the SI standard quantities for length, time, mass and electric current, together with their symbols, units and abbreviations.
2. Identify basic and derived quantities.
3. Convert from one unit to another.
4. List and classify the possible sources of errors encountered when making a measurement.

5. Calculate the percentage error for a result.
6. Convert from exponential (scientific notation) to decimal and vice versa.
7. Arrange a set of numbers in order of magnitude.
8. Use significant figures in calculations.
9. State simple round-off rules.
10. List essential components of a laboratory report.

Scientific processes

Measurement

1. Read linear scales.
2. Estimate length, time, mass and number.
3. Locate, record and analyse primary data.
4. Locate and present relevant information from secondary data sources.
5. Write clear and logical laboratory reports.

Graphing

1. Draw graphs to illustrate the relationships between physical quantities in the form:

   $y \propto x$, $y \propto x^2$, $y \propto 1/x^2$, $y \propto 1/x$, $y \propto \sqrt{x}$, sine graph
2. Plot a graph from experimental data and interpret graphs. Be able to interpolate and extrapolate graphs.
3. Use graphical means to analyse a set of experimental data and determine the relationship between the quantities involved.

Complex reasoning processes

Use complex reasoning to solve challenging problems, make logical decisions and use creative and/or critical thinking.

Recommended practical work

1. Use digital or analogue instruments to measure length, time and mass.
2. Complete an experiment that involves determining a relationship from a graph.

Topic 2—Forces and motion

Because motion is so common to our everyday experiences, one of the important functions of physics is to provide a description of motion (**kinematics**) which investigates *how* objects move and an analysis of motion (**dynamics**) which investigates *why* objects move in the way they do. The study of motion and forces is an essential prerequisite for other topics in this course (3, 5, 6 and 7). In the early stages of this topic, candidates should be reminded that the types of motion studied are highly idealised and may seem to have little to do with the real world as we observe it. However, it is essential that candidates first investigate the simple and idealised motions and their causes to obtain a firm understanding of the basis of dynamics. When this goal has been achieved, they are in a position to apply their knowledge to the real but more complex world.

Learning experiences

Although it is important that candidates gain confidence in solving problems involving a mathematical treatment, it is essential that they fully understand the underlying concepts involved. Such an **intuitive** understanding can be attained in a number of ways. Some suggestions are:

- experiments on motion and forces (using ticker-timers, multiflash photography, etc.) and a graphical analysis of the results
- exposing candidates to problems that, even if they involve a mathematical treatment, have a direct relevance to their experience in everyday life
- challenging candidates' preconceived ideas on motion and force by posing thought-provoking questions. The following two serve as examples.

Example 1: When a ball is thrown up vertically, what is its acceleration at the position of maximum height where its velocity is zero? (Most candidates respond by saying the acceleration is zero.)

Example 2: Why do astronauts 'float' inside a space shuttle that freely orbits around the earth? (Most candidates respond by suggesting that the gravitational force is zero, even if the space shuttle is, say, 200 km above the earth).

Specific objectives—Topic 2: Forces and motion

Knowledge of subject matter

Linear motion

1. Explain the terms distance, displacement, speed, velocity and acceleration. Use correct units.
2. Describe the motion of objects using these terms.
3. Distinguish between instantaneous and average velocity.
4. Solve problems using the following equations of motion:

   $v = s/t$; $v = u + at$; $s = ½(u + v)t$; $s = ut + ½at^2$;$v^2 = u^2 + 2as$.
5. Describe the motion of objects moving vertically under gravity.
6. Explain how the acceleration due to gravity can be determined.

Vectors

1. Identify the difference between scalar and vector quantities and give examples.
2. Add and subtract vectors by calculation.
3. Multiply vectors by numbers and scalars.
4. Resolve a vector into two components at right angles to each other (including inclined planes).
5. Represent vector quantities graphically as directed line segments.
6. Use vectors to solve simple problems.

Forces

1. Define the term force. Describe everyday situations where forces act.
2. Identify the difference between gravitational mass and weight.
3. Identify the difference between balanced and unbalanced forces.
4. State Newton's three laws of motion and use them to solve simple problems ($F = ma$, $W = mg$).
5. Identify examples of action—reaction forces.
6. Explain what friction is and describe its effects. Solve simple problems involving friction as a drag force.

Curvilinear and projectile

1. Identify the difference between rectilinear and curvilinear motion.
2. Identify the difference between horizontal and angular projection.
3. Define the terms: projectile and trajectory.
4. Resolve initial velocity of a projectile into vertical and horizontal components.
5. Describe the forces acting on projectiles and calculate the time of flight, range, impact velocity and maximum height of a projectile.

Newton's Law of Universal Gravitation

1. State Newton's Law of Universal Gravitation ($F = Gm_1m_2/d^2$).
2. Identify the difference between gravitational field strength ($g = F/m$) and acceleration due to gravity.
3. Explain what a gravitational field is.

Scientific processes

Linear motion

1. Describe uniformly accelerated motion by plotting, interpreting and using graphs (s/t, v/t, a/t).
2. Describe relationships between these graphs of motion.
3. Tabulate and analyse experimental data relating to motion.
4. Quantify, analyse and interpret data generated, for example, by ticker-timers, stroboscopes, electronic timers or computer interfaces using mathematical and vectorial operations.
5. Record and organise data in calculations, reports and tables using correct units of measurement.
6. Select suitable devices to record motion.

Vectors

1. Draw free-body and vector diagrams of applied forces.
2. Examine graphically the result of forces on objects.
3. Identify sources of measurement errors in Newton's Law experiments.
4. Design simple experiments to test the ways of increasing or decreasing friction.

Newton's Law of Universal Gravitation

1. Graph gravitational field strength against displacement for a simple gravitational system.

Complex reasoning processes

1. Use complex reasoning to solve challenging problems, make logical decisions and use creative and/or critical thinking.
2. Solve problems involving combinations of displacement, time, velocity and acceleration.
3. Solve problems involving Newton's laws and frictional forces in more complex situations.
4. Solve problems on linear or projectile motions.
5. Predict motion of projectiles in cases where friction is significant.

Recommended practical work

1. Complete an experiment to obtain data for the following graphs:

   (a) displacement versus time; (b) velocity versus time.
2. Complete an experiment to investigate vertical motion under gravity in order to evaluate 'g'.

Topic 3—Energy and momentum

In topic 2, attention was focused on situations that involved a single object acted on by a constant unbalanced force. However, in the real world, we are dealing with situations that involve a number of objects that are interacting or colliding with each other. Furthermore, the forces involved are not constant in most situations. In this topic, we investigate the concepts of energy and momentum which culminate in the laws of conservation of these quantities.

These two conservation laws, particularly when used in combination, facilitate powerful and elegant solutions of a wide range of problems. These situations do not require a detailed knowledge of the forces involved but only of the initial and final conditions. Furthermore, this topic has a social significance in that it reinforces the candidate's appreciation that the production of a particular form of energy is at the expense of other forms of energy.

The study of this topic is a necessary prerequisite to topics 5 and 7. Although this topic covers only kinetic, elastic potential and gravitational potential energies, other forms of energy (e.g. electrical and nuclear) will be covered in greater detail in other topics.

Learning experiences

1. Experiments on energy and momentum. Such experiments may involve: colliding dynamic carts; gliders on air tracks; pucks on air tables; rolling a ball-bearing down an incline; dropping a mass attached to a spring.
2. Exposing candidates to situations that have a direct relevance to their experience in everyday life (sport, skiing, etc.) and solutions of problems related to these experiences.

3. Reinforcing the candidate's awareness of the power and elegance of the conservation laws by contrasting such solutions to those involving the application of Newton's second law.

Specific objectives—Topic: Energy and momentum

Knowledge of subject matter

Energy

1. List various sources and types of energy.
2. State examples of the energy transformations GPE ↔ KE, EPE ↔ KE.
3. Define work, kinetic energy, potential energy and power and state their units ($W = Fs \cos\theta$; $P = W/t$; $KE = ½mv^2$; $EPE = ½ kx^2$; $GPE = mgh$; $|F| = |kx|$).
4. Calculate energy transfer using the definition of work.
5. Solve simple problems involving energy changes.
6. State the principle of conservation of energy in a closed system.
7. Describe elastic potential energy. Solve simple problems involving elastic potential energy.

Momentum

1. Define momentum and impulse.
2. Calculate vectorially the momentum of an object ($p = mv$).
3. Calculate vectorially the impulse given to an object($Ft = \Delta p$).
4. State the law of conservation of momentum and use it to solve simple problems.
5. Define elastic and inelastic collisions.
6. Identify the differences between elastic and inelastic collisions in terms of conservation of total energy, kinetic energy and momentum.

Scientific processes

1. Interpret and analyse force-displacement graphs to determine work done, change in kinetic energy or potential energy.
2. Calculate spring constant from experimentally obtained graphs.
3. Interpret/analyse/construct total energy vs. distance graphs where total energy shows KE and GPE changes.
4. Interpret/analyse experimental data for elastic linear collisions.

Complex reasoning processes

1. Use complex reasoning to solve challenging problems, make logical decisions and use creative and/or critical thinking.
2. Analyse changes in kinetic and potential energy in falling objects and vibrating springs.
3. Interpret/analyse experimental data involving elastic collisions.

Recommended practical work

1. Perform an experiment involving a linear elastic collision between two objects in order to calculate momentum changes and elastic behaviour.
2. Perform an experiment to show energy changes in an oscillating mass.

Topic 4—Wave motion and optics

Candidates will be familiar with examples of energy being transported from one place to another, together with the transfer of material. For example, fossil fuels are taken to the place of their combustion in order to release energy, and kinetic energy is associated with moving bodies.

In this topic, candidates should realise that energy can be transported by wave motion, which does not involve the transfer of material. The properties and characteristics of waves may be investigated as they travel in a given medium, reflect, move from one medium to another, undergo interference and diffract.

The concepts may be taught using several of the waveforms belonging to mechanical waves, acoustic waves or electromagnetic waves.

This topic also looks at the application of some of the wave-model concepts to optical devices. In the core, the theoretical bases of reflection and refraction are developed.

Learning experiences

The candidate may be exposed to various types of practical investigations or demonstrations such as:

- reflection and interference of waves generated in springs
- properties of water waves in ripple tanks
- interference of sound waves using an air column or a stretched vibrating string
- Young’s double slit experiment
- CRO wave form demonstrations
- use of optics kits to examine refraction
- the application of prisms to illustrate refraction, total internal reflection, and spectra
- library research into the history of the physics of light.

Specific objectives—Topic 4: Wave motion and optics

Knowledge of subject matter

Properties of waves

1. Describe how waves are created.
2. Distinguish between the types of waves—transverse and longitudinal in either progressive or stationary mode.
3. Recognise that waves carry energy and where this energy comes from.
4. Define and use the terms associated with waves—frequency, wavelength, period, troughs, crests, propagation, compression, rarefaction, mechanical wave, electromagnetic wave and velocity.
5. State and apply the wave equation $v = f\lambda$ and the relationship $f = 1/T$.
6. State and apply the rules with regard to the transmission and reflection of waves from fixed ends, free (open) ends and from one medium to another.
7. State and apply the principle of superposition of waves.
8. Identify the conditions necessary for a standing wave to form; label the parts of a standing wave and state the means of creating such a wave.
9. State Huygens’ theory and use it to explain wave effects.

Waves in two dimensions

1. Identify/deduce the meaning of the following terms: speed of wave, amplitude, pulse, node, anti-node, progressive wave, standing wave, phase.
2. Describe and explain the diffraction of water waves through single slits of different widths and around obstacles.
3. Describe the reflection and refraction of waves in water.
4. Identify/deduce the terms:
   (a) direction of propagation
   (b) angle of incidence
   (c) angle of reflection
   (d) angle of refraction.
5. Recognise wave motion as a means of energy transfer.
6. Solve simple problems involving reflection and refraction of water waves: ($n_1 \sin \theta_1 = n_2 \sin \theta_2$; $n_1v_1 = n_2v_2$).

Refraction

1. Define the term 'refraction'.
2. Give examples of effects that show the refraction of light.
3. Define 'refractive index' in terms of the following formulae and use them to solve problems:

   $n_1 \sin \theta_1 = n_2 \sin \theta_2$; $n_1v_1 = n_2v_2$
4. Identify the difference between real and apparent depth in water.
5. Define critical angle and describe conditions necessary for total internal reflection (qualitative only).

Interference

1. State the relative location of the following regions of the electromagnetic spectrum: UV, visible, IR.
2. Define the following terms: interference, diffraction, path difference, nodal lines, reinforcement, coherence, phase, monochromatic.
3. Identify differences between destructive and constructive interference.
4. Describe Young's double slit interference experiment and solve problems related to it.
5. State and use the following formulae in simple situations:
   (a) For points on a maxima: $d \sin\theta = dx_n/L = n\lambda$
   (b) For points on a minima: $d \sin\theta = dx_n/L = (n- ½)\lambda$
   (d) Path difference = dx_n/L
   (e) Fringe spacing: $\Delta x = \lambda L/d$
6. Relate how wavelength and slit width effects diffraction and interference patterns.
7. Explain why diffraction of light is difficult to see.

Scientific processes

Property of waves

1. Identify features of waves from wave diagrams and determine the motion of particles of these waves.
2. Determine the speed, wavelength, and frequency of waves from graphical representations of waves.
3. Use the principle of superposition to construct the resultant wave from two intersecting waves.

Waves in two dimensions

1. Predict direction of reflected and/or refracted wave from given incident wave patterns in water.
2. Diagrammatically show the wave pattern produced by interfering waves.
3. Identify nodal and anti-nodal lines on an interference pattern.
4. Investigate standing waves patterns in water.
5. Draw diagrams to show reflection of waves in water from straight and curved boundaries.

Refraction

1. Draw diagrams to show the passage of light through rectangular and semicircular blocks and a prism.
2. Predict and deduce the direction of light through a block of glass and other materials.
3. Write an experimental report on Snell's Law.

Interference

1. Identify and explain physical situations involving interference.
2. Draw and recognise the interference pattern of water waves from sources in phase.

Complex reasoning processes

1. Use complex reasoning to solve challenging problems, make logical decisions and use creative and/or critical thinking.
2. Predict outcomes of pulse and wavetrain interactions on a spring at free and fixed ends.
3. Predict outcomes of other wave interactions (e.g. water, sound, light).
4. Solve complex problems on diffraction (double slit), interference, reflection and refraction.
5. Analyse data obtained from path differences in interference patterns using coherent sources.

Recommended practical work

1. Investigate the behaviour of both longitudinal and transverse waves on springs in relation to:
   (a) reflection from a fixed and a free end
   (b) transmission/reflection at a medium boundary.
2. Perform a double slit type experiment (Young's experiment) to measure the wavelength of monochromatic light.
3. Perform an experiment to determine the refractive index of a transparent substance (Snell's Law).

Topic 5—Electricity and electronics

This topic will extend and overlap the material of topics 2, 3 and 7. The concepts of force and field can be re-emphasised. The new ideas of electromotive force (EMF) and electrical potential difference are fundamental to the notion of electric circuits and controlling electrical energy. These concepts lead to an understanding of voltage, current, resistance and electronic components. In a modern physics context the understanding of differences between DC and AC behaviour of resistance, capacitance and inductance leads to such applications as electrical engineering and telecommunications. The discovery of semiconductors and integrated circuits has revolutionised our modern world with its computer-based technologies. The theme of this topic should allow a development of ideas from basic component and circuit behaviour to semiconductors and integrated circuits through to extension work on VLSI chips, microprocessors and microcomputers. This topic lends itself to a wide variety of practical investigations. An ability to read and construct circuits in a hands-on manner is vital within this core topic.

Learning experiences

The candidate may be exposed to various types of practical investigations or demonstrations such as:

- use of simple electrostatic generation and testing equipment to show the nature of attraction, repulsion and induction laws
- investigation of the nature of the electrostatic field surrounding point charges and between parallel plates
- plotting of the electrostatic fields using simple measurement of equipotentials in the field
- connecting simple circuits and using meters to measure current, EMF, and potential difference around the circuit
- verification of Ohm's Law with a simple series circuit or voltage divider network
- construction and testing of a diode rectifier and smoothing capacitor circuit to convert AC to DC voltage
- construction and testing of a simple NPN transistor circuit to measure voltage gain.

Specific objectives—Topic 5: Electricity and electronics

Knowledge of subject matter

Electric charges and fields

1. Define and give examples of the process of electric charging by friction (electrification) and by induction.
2. List the properties of electrostatic force and types of charge (+/–).
3. State Coulomb's Law $F = kq_1q_2/r^2$
4. Explain the theory of atomic structure as it applies to electrostatic charging.
5. Describe the differences between conductors, insulators and semiconductor materials.
6. Sketch point source and parallel plate electric field patterns.
7. Explain qualitative and quantitative treatment of the field between parallel plates $V = Ed$.

Electric currents

1. Identify electricity as static or current.
2. Define electric current and the unit ampere. Use the formula $q = It$.
3. Define electric current, electrical resistance, electrical potential difference, voltage, electrical energy and electrical power.
4. State and use the mathematical form of Ohm's and Kirchhoff's electrical circuit analysis laws: $V = IR$; $P = VI$; $W = VIt$
5. State and apply rules for calculating total resistance for series and parallel combinations of resistors:
   $R_{TOT} = R_1 + R_2 + R_3 + \ldots$; $1/R_{TOT} = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$
6. Recognise the difference between series and parallel connections of both circuit components and sources of EMF.

Electric circuits and electronics

1. Recognise correct symbols to represent the following electronic devices and circuits elements: DC–AC sources, earth, switch, lamp, resistor, variable resistor, voltmeter, ammeter, capacitor, diode, NPN transistor.
2. Recall the method of correct use of ammeters and voltmeters.
3. Recall practical applications of resistors or their combinations.
4. Describe the nature of P and N type semiconductors in terms of their crystalline structures and charge carriers during electrical conductivity.
5. Define threshold voltage for a diode.
6. Explain the operation of a PN diode and its use in full-wave and half-wave AC rectification.
7. State the bias conditions necessary for conduction in a PN diode.

Electronic systems

1. Define the terms transistor, amplifier.
2. Explain the operation and semiconductor action of an NPN bipolar transistor.
3. Define the transistor current gain factor ($\beta = I_C/I_B$) for common emitter amplifier circuit.
4. Explain how a transistor can be used as a switch and as an amplifier.
5. Recall the method of biasing a transistor so that it will behave as a DC current amplifier.

Scientific processes

Electric charges and fields

1. Interpret diagrams and written descriptions to analyse the process of charging objects by conduction and by induction.
2. Record observations of electrostatic interactions using detecting and generating instruments.
3. Write reports using electrostatic units of measurement correctly in calculation and tables.

Electric currents

1. Interpret electrical circuit diagrams.
2. Identify the correct meter to use in the analysis of electrical circuits.
3. Predict, using graphical techniques and calculation, such unknown quantities in electrical situations as voltage, current or resistance.
4. Draw an operating electrical circuit using correct circuit symbols.

Electric circuits and electronics

1. Communicate electronic information via an electronic circuit diagram.
2. Design simple circuits to perform a given task or gather numerical data.

Electronic systems

1. Sketch correctly a block diagram or schema for a given circuit.
2. Design simple transistor circuits to perform a given task or gather electronic data.
3. Graph data to illustrate current gain for a simple transistor.
4. Interpret signal input-output diagrams to determine a circuit's behaviour.

Complex reasoning processes

1. Use complex reasoning to solve challenging problems, make logical decisions and use creative and/or critical thinking.

Electric currents

1. Analyse complex DC circuits qualitatively and quantitatively including applications of Ohm's Law and Kirchhoff's laws and assessment of charge, resistance, voltage, current, energy and power.
2. Select relevant properties of electrical circuit systems to predict their behaviour or output under a given set of conditions.

Electric circuits and electronics

1. Solve challenging problems using interconnected relationships between resistance, DC voltage and current including complex circuit analysis.
2. Derive new relationships algebraically or graphically from given data.
3. Select the relevant properties of an electronic component to predict its behaviour in any given circuit.
4. Model complex electrical circuits with the use of block diagrams as an analysis tool.

Electronic systems

1. Solve challenging problems involving DC current gain and switching action using transistor theory and circuits.
2. Select relevant knowledge and data to satisfactorily explain the operation of complex circuits.
3. Model complex electronic circuits with the use of block diagrams as an analysis tool.

Recommended practical work

1. Investigate the potential drops, resistance and current in series and parallel circuits.
2. Investigate the use of diodes in full and half-wave rectification.
3. Investigate the use of a transistor as a switch and a current amplifier.

Topic 6—Magnetism and electromagnetism

The core material of this topic should continue to expose the candidates to physical field ideas and the nature of force. As such, it continues to develop ideas from topics 2, 3 and 7 and should be integrated with these topics through such mechanisms as force field comparisons to other types existing in physics such as gravitational or electric fields. The topic lends itself to a wide variety of practical investigations that demonstrate magnetic and electromagnetic effects. This topic contains important principles that the candidate should comprehend as underlying most modern technology—for example, induction principles, electrical meter movements and transformers, audio and video technology, AC/DC energy generation, medical, chemical, analytical instrumentation and navigational technology. The historical importance of Oersted’s, Faraday’s and Lenz’s laws may also be emphasised.

Learning experiences

The candidate may be exposed to various types of practical investigations or demonstrations such as:

- measurement of the Earth’s magnetic field strength by vector comparison to a square coil field.
- measurement of magnetic field strength by the simple current balance technique.
- AC/DC electromagnetic generation principles and simple meters and motors.
- measurement of voltage transformation under step-up or step-down modes of connection.
- estimation of the mass of the electron from radius of curvature in a known solenoid coil field strength.

Specific objectives—Topic 6: Magnetism and electromagnetism

Knowledge of subject matter

Electromagnetism

1. State the laws of magnetic pole interactions.
2. List the characteristics of magnetic fields as well as the rules and conventions for their representation.
3. Recognise the significance of the discoveries of Oersted and Faraday in the development of electromagnetics.
4. Calculate, using simple situations, the nature of magnetic fields surrounding wires, flat coils and solenoid coils: $B = kI/r$; $B = 2\pi kIN$
5. State hand-rule conventions for determining direction of magnetic fields about wires, loops and solenoids.
6. Describe the factors influencing the magnitude and direction of magnetic fields including simple vector combinations.
7. Define and calculate the magnetic flux in a region of space:
   Formula: $\phi = BA \cos\theta$.
8. Describe and calculate forces (vectorially) acting on a moving charge in a magnetic field ($F = Bqv \sin\theta$; $F = BIL \sin\theta$).
9. State hand-rule conventions for determining forces acting on moving charges in a magnetic field.
10. Calculate the force acting between parallel conductors in a magnetic field. State its direction.
11. Define ampere in terms of force between parallel current-carrying wires.
12. Describe the basic components and method of operation of simple DC motors as an application of the motor principle.

Electromagnetic induction

1. Define the principle of electromagnetic induction.
2. Deduce the direction of induced current using Lenz’s Law.
3. State Faraday’s law of electromagnetic induction.
4. List the factors that affect the magnitude of the induced EMF in a conductor due to changing magnetic flux ($\Delta\phi$); $EMF = -N\Delta\phi/\Delta t$; $EMF = Blv$.
5. Perform simple calculations using the laws of electromagnetic induction.
6. State hand-rule conventions for determining the direction of induced currents or voltage in a wire, loop or solenoid.
7. Apply a knowledge of induction principles to explain the operation of simple devices.

Scientific processes

1. Sketch magnetic field patterns of single and multiple magnets, electromagnets or combinations of all three.
2. Predict the behaviour of magnets or electromagnets when any given interaction is presented.

3. Classify magnetic substances on the basis of their behaviour within any given field.
4. Graph and interpret the induced EMF arising from a coil rotating in a magnetic field.
5. Quantify and organise data with correct units in magnetics and electromagnetics.

Complex reasoning processes

1. Use complex reasoning to solve challenging problems, make logical decisions and use creative and/or critical thinking.
2. Integrate several pieces of basic magnetic or electromagnetic theory in order to predict the outcome of a complex interaction of fields.
3. Research and demonstrate creative thinking in understanding new applications of electromagnetic principles.

Recommended practical work

1. Investigate the magnetic field of: (a) a long straight current-carrying wire; (b) a current-carrying solenoid.
2. Demonstrate the force on a straight current-carrying wire, when it is in a magnetic field.
3. Investigate induced current when a bar magnet is moved parallel to the axis of a solenoid.

Topic 7—Atomic and nuclear physics

Atomic and nuclear physics marks the beginning of 'Modern Physics' as distinct from the Newtonian concepts of space, time and matter. In this topic the historical development is a useful way of illustrating the problems confronted by theorists in developing abstract models of phenomena which are not only abstract themselves but complex as well. Topics 1, 2, 3 and 6 underpin this topic.

One aspect that concerns us all is ionising radiation—both from natural and artificial sources. Although it is useful to medicine and industry, it is also very hazardous. Both protection and risk estimation are important for workers and the general community. This is helped by an understanding of the sources and properties of radiation. The other aspect of concern is that of nuclear energy. This too holds both a promise and a threat for humanity. Its potential in both civilian and military areas has given rise to considerable scientific activity. Informed discussion and decision making require understanding of the principles of nuclear energy.

Learning experiences

The candidate may be exposed to various types of practical investigations or demonstrations such as:

- half-life of a radioactive isotope: ^{137}Cs/^{137}Ba minigenerator or ^{32}P sample if available
- use of IEC Magic Source and Digital Counter.

Specific objectives—Topic 7: Atomic and nuclear physics

Knowledge of subject matter

Atomic structure

1. Describe Rutherford's alpha particle and gold foil experiment.
2. Describe the historical development of the physics of atomic structure including the contributions of Crooke, Thomson, Millikan's oil drop experiment, and Rutherford.
3. Explain what radioactivity is and describe how it was discovered (including Becquerel's contribution).
4. Describe the structure of the atom. List the properties of protons, neutrons and electrons.
5. Define the terms atomic number and atomic mass.
6. Explain what an isotope is and give examples.
7. Describe the various forces that exist in an atom.

Radioactivity

1. Explain what is meant by atomic number, mass number (or atomic mass), isotope, proton, neutron, radioactivity, radioactive decay, alpha radiation, beta radiation, gamma radiation, nuclear bombardment, half-life, artificial radioactivity, nuclear fission, nuclear fusion.
2. List the common features or properties of radioactive elements.
3. State the formation and properties of alpha, beta and gamma radiation (including penetrating power).
4. State and recognise equations representing radioactive decay.
5. Define the term 'half-life'.
6. Distinguish between nuclear fission and nuclear fusion. Give examples of each.
7. Describe the conditions for a chain reaction.

Quantum theory

1. Describe Einstein's development of photoelectric effect.
2. Explain the meaning of a KE versus frequency graph and Planck's constant.

Scientific processes

1. Classify the basic particles of an atom based on their properties.
2. Model the structure of the nucleus from given data.
3. Infer atomic compositions given the atomic numbers and atomic mass.
4. Analyse and balance nuclear equations.
5. Interpret graphs of radioactive decay to determine half-lives.
6. Predict the nature of radioactive particles from their attenuation in passing through matter or their path shape in electric or magnetic fields.
7. Predict the effect on the $E_{K(max)}$ versus frequency graph of variations in the photoelectric material or intensity of incident radiation.
8. Interpret tabulated data to predict emitted photon frequency and wavelength.

Complex reasoning processes

1. Use complex reasoning to solve challenging problems, make logical decisions and use creative and/or critical thinking.
2. Solve novel problems involving atomic structure and composition.
3. Critically analyse the relevance of the different models of the atom.
4. Solve challenging problems using formulae of photoelectric effect and photon energy.

Recommended practical work

Investigate radioactive decay by using a Geiger counter and radioactive specimen (or by simulation).

8. ASSESSMENT

8.1 The examination

The examination will consist of two papers:

- Paper One, of up to 2.5 hours
- Paper Two, of up to 2 hours.

Each paper will have 10 minutes perusal time.

Paper One will assess knowledge of subject matter and the ability to use scientific processes in simple situations. Section A will consist of multiple-choice questions and section B will contain short response items. Paper 1 will be ‘closed book’ but tables of physical constants and formulae mentioned in the specific objectives of this syllabus will be provided. Across the range of questions there will be a balance of approximately 60 per cent for knowledge objectives (composed of approximately 20 per cent for the recall component and 40 per cent for the application component) and 40 per cent for scientific process objectives. These questions will be labelled as *knowledge* or *scientific processes*.

Paper Two will consist of a small number of extended-answer questions of varying levels of difficulty assessing complex reasoning processes. Paper 2 will be an open book examination. In this examination students will be permitted to bring to the examination room any relevant paper-based written or printed material.

The papers will not assess *all* objectives but will reflect a balance across the whole course.

Neither paper will attempt a ‘hands-on’ test of the recommended practical work specified in the syllabus. The papers will, nevertheless, require that the candidate be familiar with the equipment and materials used in the laboratory. Sample results may be provided and the candidates may be asked questions which require analysis and interpretation of the data. **It would be to the advantage of the candidates to complete the practical work as specified in the syllabus.**

In both papers, the candidate should:

(a) use correct SI units

(b) include written explanation to make the development of any argument meaningful

(c) draw graphs, where necessary, which have axes clearly labelled and calibrated

(d) express numerical answers to a reasonable level of precision.

8.2 Exit levels of achievement

Following completion of the examination, each candidate will be awarded one of the following five exit levels of achievement:

- Very High Achievement—VHA
- High Achievement—HA
- Sound Achievement—SA
- Limited Achievement—LA
- Very Limited Achievement—VLA

To be awarded a particular exit level of achievement, candidates must achieve to the standard specified in each criterion, that is: Knowledge of subject matter, Scientific processes, Complex reasoning processes. When a candidate's achievement is uneven, resulting in different standards in each criterion, a slight trade-off may be possible (see section 8.3).

The exit levels of achievement are thus defined in terms of a candidate's achievement in each criterion as shown in following table.

Table of minimum standards associated with exit criteria

	Very High Achievement	High Achievement	Sound Achievement	Limited Achievement	Very Limited Achievement
Knowledge of subject matter	A very high ability to recall and apply knowledge in simple situations	A high ability to recall and apply knowledge in simple situations	A satisfactory ability to recall and apply knowledge in simple situations	A limited ability to recall and apply knowledge in simple situations	A very limited ability to recall and apply knowledge in simple situations
Scientific processes	A very high ability to succeed in simple scientific process tasks—collecting and organising data, processing information, making simple judgments, communicating information in various contexts, devising and designing simple/single step investigations	A high ability to succeed in simple scientific process tasks—collecting and organising data, processing information, making simple judgments, communicating information in various contexts, devising and designing simple/single step investigations	A satisfactory ability to succeed in simple scientific process tasks—collecting and organising data, processing information, making simple judgments, communicating information in various contexts, devising and designing simple/single step investigations	A limited ability to succeed in simple scientific process tasks	A very limited ability to succeed in simple scientific process tasks
Complex reasoning processes	A high ability to use complex reasoning in challenging situations involving the candidate's understanding of subject matter and a high ability to use scientific processes at an advanced level.	Competence in using complex reasoning in challenging situations involving the candidate's understanding of subject matter and competence in using scientific processes at an advanced level.	Some success in using complex reasoning in challenging situations involving the candidate's understanding of subject matter and some success in using scientific processes at an advanced level.		

8.3 Trade-off

When data in a candidate's profile of achievement are uneven, resulting in different standards for some of the exit criteria, a trade-off will be considered if there is a deficiency in the achievement on a single criterion.

Under these conditions:

- A slight deficiency in knowledge of subject matter may be offset by a comparable excess in scientific processes or vice versa

  or

- A slight deficiency in knowledge of subject matter or scientific processes may be offset by a comparable excess in complex reasoning processes.

A 'slight' deficiency is taken to be a deficiency of less than one-third of the relevant level of achievement.

Only one trade-off is possible.

No other trade-offs, other than those listed above, are permissible for knowledge of subject matter, scientific processes or complex reasoning processes.

9. GLOSSARY

Complex reasoning processes. Complex reasoning processes are those higher order or more involved problem-solving processes that provide challenge to candidates and hence discriminate across the range of candidate abilities. They are likely to include responding to novel tasks; making logical decisions involving the selection of relevant knowledge and/or data; and using creative and/or critical thinking, which could include identification of assumptions, fallacies, valid/invalid conclusions, adequacy of data, and the proposing of alternative theories. Complex reasoning processes might also involve advanced level challenges derived from the knowledge of subject matter or scientific processes. The candidate who is a novice to the context and/or material necessary to demonstrate use of complex reasoning is likely to perceive difficulty in such challenging situations.

Conditions. The conditions related to the conduct of the examination can be found in the *External Examination Handbook.* Candidates should be familiar with the handbook's contents.

Exit criteria. Exit criteria are the broad dimensions for which standards are written and are used to determine exit levels of achievement. They are Knowledge of subject matter, Scientific processes and Complex reasoning processes.

General objectives. The general objectives are described in terms of what a candidate should gain from undertaking this course of study (see page 5).

Knowledge. Knowledge is the recall of learned material and its simple application (see page 6).

Learning experiences. These are the experiences which a candidate should be exposed to in a course of study. The candidate and/or teacher will need to select those experiences which should promote the attainment of the objectives of the course of study (see page 9).

Level of achievement. Following completion of the examination, a candidate will be awarded one of the five levels of achievement: Very High Achievement—VHA; High Achievement—HA; Sound Achievement—SA; Limited Achievement—LA; Very Limited Achievement—VLA.

Manipulative skills. Manipulative skills include the operation of scientific and experimental equipment and materials proficiently and safely (see page 5). They are not assessed directly in the external examination.

Profile of achievement. A profile of achievement is a record of the candidate's levels of achievement in each of the three exit criteria. A trade-off may be permitted when there is uneven performance across the three criteria. A single exit level of achievement is derived from these three levels of achievement.

Scientific processes. Scientific processes are those processes that involve collection and organisation of data, processing of information, making simple judgments, communicating information in various contexts, devising and designing simple and/or single-step investigations at a simple level.

Trade-off. When data in a candidate's profile of achievement are uneven, resulting in different standards for some of the exit criteria, a trade-off will be considered subject to certain rules (see section 8.3).

10. RESOURCES

Following are suggested texts commonly used in Queensland secondary schools that offer Physics. These are current at the time of publication. Candidates should also refer to section 6 Organisation for other suggested types of resources.

Eastwell, P. 1996, *Physics Spectrum: Constructing and understanding*, McGraw-Hill, Roseville, NSW. 0074702602

Hewitt, P. 1998, *Conceptual Physics*, 3rd edn, Longman, San Francisco, CA. 0201332876. (Student's edition, teacher's edition, laboratory manual, and resource package available.)

Lofts, G., O'Keefe, D., Robertson, P., Pentland, P., Hill, B. & Pearce, J. 1997, *Jacaranda Physics I*, Jacaranda, Milton, Queensland. 070163331x

Lofts, G., O'Keefe, D., Robertson, P., Pentland, P., Hill, B. & Pearce, J. 1998, *Jacaranda Physics II*, Jacaranda, Milton, Queensland. 0701633301

Millar, G., Chapman, R., Burrows, K., Bail, D. & Fry, C. 1996, *Heinemann Physics 11*, Heinemann, Melbourne. 0858599295

Millar, G., Chapman, R., Gersh, H., Burrows, K., Bail, D. & Fry, C. 1997, *Heinemann Physics 12*, Heinemann, Melbourne. 0858599309

Walding, R., Rapkins, G., & Rossiter, G. 1999, *New Century Senior Physics*, Oxford University Press, Melbourne.