AQA

GCE

AS and A Level Specification

Physics B: Physics in Context

AS exams 2009 onwards
A2 exams 2010 onwards

Contents

Vertical black lines indicate a significant change or addition to the previous version of this specification.

1 Introduction

1.1 Why choose AQA?

It's a fact that AQA is the UK's favourite exam board and more students receive their academic qualifications from AQA than from any other board. But why does AQA continue to be so popular?

- **Specifications**
  Ours are designed to the highest standards, so teachers, students and their parents can be confident that an AQA award provides an accurate measure of a student's achievements. And the assessment structures have been designed to achieve a balance between rigour, reliability and demands on candidates.

- **Support**
  AQA runs the most extensive programme of support meetings; free of charge in the first years of a new specification and at a very reasonable cost thereafter. These support meetings explain the specification and suggest practical teaching strategies and approaches that really work.

- **Service**
  We are committed to providing an efficient and effective service and we are at the end of the phone when you need to speak to a person about an important issue. We will always try to resolve issues the first time you contact us but, should that not be possible, we will always come back to you (by telephone, email or letter) and keep working with you to find the solution.

- **Ethics**
  AQA is a registered charity. We have no shareholders to pay. We exist solely for the good of education in the UK. Any surplus income is ploughed back into educational research and our service to you, our customers. We don't profit from education, you do.

If you are an existing customer then we thank you for your support. If you are thinking of moving to AQA then we look forward to welcoming you.

1.2 Why choose Physics B: Physics in Context?

- Physics B: Physics in Context places the subject firmly in a range of contemporary contexts. It introduces students to new and exciting areas of physics and develops essential knowledge and understanding – all through a context and applications led approach to capture the interest of students.
- The specification is fully supported by resources from AQA and a range of complementary support materials produced in conjunction with Nelson Thornes, to give teachers confidence in delivery.
- The examination papers will reflect the quality and reliability established for the AQA predecessor specifications.
- Internal assessment of practical work is a key feature of the specification. There are two routes to the internal assessment.
  - Route T provides continuity in style and format from AQA's GCSE physics assessment model. This is achieved through assessment of practical skills (PSA) and an individual skills assessment (ISA) in Unit 3 and Unit 6.
  - Route X provides a scheme of internal assessment through a verification of practical skills undertaken throughout the course and an externally marked practical test.
- The specification provides opportunities to develop *How Science Works* by linking the general criteria on the nature of science to specific topics throughout the specification. Internal assessment gives students a deep awareness of how science in practice works.
- The specification also provides clear continuity from GCSE and progression to university.

1.3 How do I start using this specification?

Already using the existing AQA GCE Physics specifications?

- Register to receive further information, such as mark schemes, past question papers, details of teacher support meetings, etc, at **http://www.aqa.org.uk/rn/askaqa.php**. Information will be available electronically or in print, for your convenience.
- Tell us that you intend to enter candidates. Then we can make sure that you receive all the material you need for the examinations. This is particularly important where examination material is issued before the final entry deadline. You can let us know by completing the appropriate Intention to Enter and Estimated Entry forms. We will send copies to your Exams Officer and they are also available on our website **http://www.aqa.org.uk/admin/p_entries.html**

Not using the AQA specifications currently?

- Almost all centres in England and Wales use AQA or have used AQA in the past and are approved AQA centres. A small minority are not. If your centre is new to AQA, please contact our centre approval team at **centreapproval@aqa.org.uk**

1.4 How can I find out more?

Ask AQA

You have 24-hour access to useful information and answers to the most commonly-asked questions at **http://www.aqa.org.uk/rn/askaqa.php**

If the answer to your question is not available, you can submit a query for our team. Our target response time is one day.

Teacher Support

Details of the full range of current Teacher Support meetings are available on our website at **http://www.aqa.org.uk/support/teachers.html**

There is also a link to our fast and convenient online booking system for Teacher Support meetings at **http://events.aqa.org.uk/ebooking**

If you need to contact the Teacher Support team, you can call us on 01483 477860 or email us at **teachersupport@aqa.org.uk**

2 Specification at a Glance

AS Examinations

AS Award 1456

Unit 1 – PHYB1 **Harmony and structure in the universe**
Written Examination – (70 marks/120 UMS), 1 hour 15 minutes
Section A: 5-8 short questions; Section B: 3-5 longer questions.
Assessing the content in Unit 1:
Module 1: The World of Music – Module 2: From Quarks to Quasars
40% of the total AS marks
20% of the total A Level marks Available January and June

Unit 2 – PHYB2 **Physics keeps us going**
Written Examination – (70 marks/120 UMS), 1 hour 15 minutes
Section A: 5-8 short questions; Section B: 3-5 longer questions.
Assessing the content in Unit 2:
Module 1: Moving People, People Moving – Module 2: Energy and the Environment
40% of the total AS marks
20% of the total A Level marks Available January and June

Unit 3 **Investigative and practical skills in AS Physics**
EITHER
PHB3T, Centre Marked Route T – 50 marks
Practical Skills Assignment (PSA – 9 raw marks)
Investigative Skills Assignment (ISA – 41 raw marks)
OR
PHB3X, Externally Marked Route X – 55 marks
Practical Skills Verification (PSV – teacher verification)
Externally Marked Practical Assignment (EMPA – 55 raw marks)
20% of the total AS marks
10% of the total A Level marks Available June only

A2 Examinations

A Level Award 2456

Unit 4 – PHYB4 **Physics inside and out**
Written Examination – (100 marks/120 UMS), 5-8 long questions, 1 hour 45 minutes
Assessing the content in Unit 4:
Module 1: Experiences Out of this World – Module 2: What Goes Around Comes Around
Module 3: Imaging the Invisible
20% of the total A Level marks Available January and June

Unit 5 – PHYB5 **Energy under the microscope**
Written Examination – (100 marks/120 UMS), 5-8 long questions, 1 hour 45 minutes
Assessing the content in Unit 5:
Module 1: Matter under the Microscope – Module 2: Breaking Matter Down
Module 3: Energy from the Nucleus
20% of the total A Level marks Available January and June

Unit 6 **Investigative and practical skills in A2 Physics**
EITHER
PHB6T, Centre Marked Route T – 50 marks
Practical Skills Assessment (PSA – 9 marks)
Investigative Skills Assignment (ISA – 41 marks)
OR
PHB6X, Externally Marked Route X – 55 marks
Practical Skills Verification (PSV – teacher verification)
Externally Marked Practical Assignment (EMPA – 55 raw marks)
10% of the total A Level marks Available June only

AS + A2 = A Level

3 Subject Content

3.1 Unit 1 PHYB1 Harmony and Structure in the Universe

3.1.1 Module 1, The World of Music

The context for this unit is communication. It takes as its themes modern techniques of communication, the nature of audio information, and the methods by which it is coded, transmitted and received. The unit emphasises the importance of digital communication as a medium for the twenty-first century. The unit covers the questions: What is a musical sound? How can music be transmitted with faithful reproduction? Is digital better than analogue? How is stored music different?

A What is music?

This section is concerned with the production of musical sounds from instruments and voice including the factors affecting pitch, loudness and recognition of instruments and voices though the presence of harmonics.

Candidates will consider the process of sound production and which frequencies need to be saved or transmitted for faithful reproduction of the original sound.

Origin of waves: sound waves originate from a vibration and complex sounds are the addition of numerous sinusoidal waves.

Nature of audio information: sound is characterised by the frequencies present and the relative amplitudes of these frequencies; appreciation of how sounds are synthesised electronically.

Basic understanding of the frequency relationships between notes in a musical scale.

Types of wave: longitudinal and transverse waves, polarised and unpolarised waves; examples of sound as longitudinal wave and electromagnetic wave as transverse wave.

Properties of waves: speed, frequency, wavelength amplitude, intensity, phase
$c = f\lambda$, calculations

Knowledge of an experiment to measure the speed of sound in air.

Intensity of sound in $\mathrm{Wm^{-2}}$; $I = \dfrac{P}{4\pi r^2}$;

Appreciation that energy from a point source is spread over a surface area equal to $4\pi r^2$ leading to the inverse-square law for the variation of intensity with distance.

intensity $\propto$ *amplitude*^{2}

Candidates will consider that the quality of music heard also depends on the condition of the listener's ears and that this can be affected by continuous exposure to loud noise/music.

Knowledge of the dB scale limited to interpreting data on sound levels; the significance of a 3 dB change; 0 dB equivalent to threshold of hearing $10^{-12}\ \mathrm{Wm^{-2}}$
Interpretation of curves of equal loudness.

How Science Works
The application of science to music and communications will be self-evident in this section. Discussion of the risks to health posed by the application of science in developing powerful loudspeakers and conflicts between neighbours on noise-related issues is relevant.

Range of normal adult human hearing and appreciation of the factors that cause deterioration in this range.

Distinction between standing (stationary) and progressive waves.
Conditions for production of a standing wave.
Graphical treatment of superposition and standing waves.

3

Candidates will look at the way sound is generated in different instruments and the different spectrum of instruments making the same general sound.

Factors affecting frequency in stretched strings including an experimental investigation;

$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

Harmonics and overtones

Candidates should be able to draw possible modes of vibration for stationary waves on stretched strings and in closed and open pipes (no calculations required).

Beat frequency of two sources = $f_1 - f_2$;

Appreciation of the use of beat frequency in accurate tuning of instruments and that 'difference frequencies' contribute to the quality of the sound heard.

3

B Analogue or digital

Candidates look at the conversion of a sound to an analogue voltage signal and then to a digital form for storage, transmission and reception. The reasons for digitising will be discussed.

How Science Works

Issues relate to ethics, application and decision-making. For example,

- the effects of digital electronics in improving communication.
- the range of information made available to decision-makers in industry, services and government.

Knowledge of recording chain:
microphones → mixer → recorder.

Knowledge of reproduction chain:
playback → amplification → loudspeaker.

Difference between analogue and digital signals.

Concept of sampling audio signals for transmission in digital form.

Concept of converting analogue audio signals into digital data using two voltage levels (knowledge of binary numbers 1 to 10 is adequate). Pulse Code Modulation.

Advantages and disadvantages of digital sampling.

Process of recovery of original digital signal from noisy signal.

Effect of noise in communication systems.

Minimum sampling rate required for effective transmission; base bandwidth,

required bandwidth = 2 × *maximum frequency in baseband* (derivation is not required)

Idea of filtration techniques for audio files, use of digital filters to provide high-pass and low-pass filtration.

The effect of rapidly changing and quickly redundant technology on the use of material resources.

Candidates should appreciate the physics of compression techniques: advantages and disadvantages of file compression, awareness of recent technology, e.g. MP3.

C Storage and playback
Using hard drives is the theme in this section

CD/DVD as storage techniques.
Candidates should be able to identify the principal components and provide a simple description of the operation of an audio CD/DVD read/write system.

How Science Works
Science has made it easy to access and copy music. The ethics of copyright infringement is an issue. How might this affect earnings and motivation of new writers/composers?

Use of a laser and diffraction grating to produce accurate tracking of data on CD.

Interference (proofs of formulae **not** required):
Young slits experiment. Need for coherent sources; path difference,

fringe spacing $w = \lambda D/s$.

Diffraction grating formula $n\lambda = d \sin\theta$;
phase difference (candidates should be able to express phase differences in degrees).

D Transmitting data
Candidates will study different methods of transmission of data between transmitter and receiver.

Electromagnetic spectrum: appreciation that electromagnetic waves are grouped into regions according to frequency/wavelength and knowledge of how the properties of the different regions define their usefulness in transmission paths.

Encoding a signal on to a high frequency carrier wave. Reasons for use of a carrier wave.
Modulation of amplitude and frequency.
Details of amplitude and frequency modulation circuits are **not** required.

Time-division multiplexing technique.

Candidates will learn ray optics in the context of optical fibre technology

Comparison of advantages and disadvantages of fibre optics, copper cable and satellites for different applications.

Law of reflection $\hat{i} = \hat{r}$
Refraction: $n_1 \sin i_1 = n_2 \sin i_2$
Refractive index of a substance is given by
$n = c/c_s$

Total internal reflection
Critical angle $\sin \theta_c = n_2/n_1$ (for $n_1 > n_2$)

$n = \sin i / \sin r$

Recall of methods of measurement of refractive index is **not** required.

Communication using Optical fibres
Need for cladding and sheath on fibre.
Energy losses in fibre optic transmission:
energy loss due to partial reflection at an interface and absorption by transmitting medium.
Effect of dispersion.
Qualitative description and explanation of transmission using graded-index fibre.

Candidates will learn about diffraction in the context of transmission of information with and without the use of satellites using radio waves and microwaves.

How Science Works
Science has provided the benefit of satellite communication for interpersonal communications. The use of tracking vehicles for road pricing may be implemented but there is a moral question about the infringement of human rights by tracking an individual's movement.

The use of mobile phones leading to proliferation of radio masts is a public concern, as is the issue related to the effects of high frequency radiation on health.

Radio communication
Appreciation that at higher frequencies only line of sight transmission is possible
Polarised waves and the need for aerial alignment.
Typical range on Earth's surface

Appreciation that long distance communication can be achieved by diffraction around the Earth's surface using long wavelengths, and by using refraction and reflection of sky waves

Satellite communication
Satellite dish consists of reflector and dipole at focus.
Frequency ranges used for Earth-satellite transmission

Advantages, disadvantages

Diffraction as an effect that 'spreads' beam of radiation from satellite dish
Half-beam width θ from $\sin \theta = \lambda/a$;
relevance to both satellites and loudspeakers
Concept of satellite footprint; calculation of size of footprint from knowledge of satellite orbital distance.

3.1.2 Module 2, From Quarks to Quasars

This unit is concerned with the scale encompassed by physics from fundamental particles to the structure of the Universe. The unit identifies the common goal and some of the achievements of particle physicists, studying matter on a small scale, and cosmologists working on the very much larger scale.
The unit demonstrates how early views of matter have proved inaccurate or incomplete and provides a limited overview of our present understanding and looks at some unanswered questions.

A Smaller and smaller
In this section candidates will study the historical development of the model for the microstructure of matter.

How Science Works
Previously-held theories have been changed by new discoveries and our existing theories are equally tenuous.

Evidence for existence of atoms.
Early ideas on indivisibility of matter; kinetic theory (basic idea only; no detail required at this stage); Brownian motion, gaseous diffusion; evidence from chemical combination.

Evidence for particle properties of electrons from deflection experiments with electron beams.
(No mathematical details for bending beams required in AS).

Evidence for a nuclear atom replacing the 'plum pudding model'; Qualitative study of the Rutherford alpha-particle scattering experiment and how such experiments lead to an estimate of nuclear size.

Constituents of the atom; protons, neutrons and electrons. Experimental discovery of proton and neutron.

Nuclear changes in alpha (α) and beta (β^-) and beta (β^+) decays.

B **Wave or particle?**
Creation of a model to explain the wave and particle phenomena exhibited by electromagnetic radiation and matter.

How Science Works
Matter and electromagnetic radiation behave differently in different experiments and scientists have modified their views and developed the quantum theory to explain this behaviour.

Ultraviolet catastrophe:
Statement of the problem and how quantum physics provides an explanation (see also black body radiation, Section E; Larger and larger).

Wave-particle duality:
Photoelectric effect as evidence for the particle nature of electromagnetic radiation:

Photon energy $E = hf = \frac{hc}{\lambda}$

Work function: Photoelectric equations
$hf = \phi + E_{k(max)}$

Candidates should be able to interpret data in tabular or graphical form.
Recall of experiments to measure ϕ or h are **not** required.

Electron diffraction as evidence for the wave nature of particles: Qualitative knowledge of demonstration

de Broglie wavelength $\lambda = \frac{h}{mv}$

3

C **The particle picture**
In this section the role of particle physics is examined.
During the unit students study theories about the range of particles that are thought to make up the universe. They will examine some theories that particle physicists believe describe the earliest moments following the big bang and the universe as we know it.
They will learn about some of the questions that remain unanswered and how physicists are trying to resolve these questions with experiments using the large hadron collider.

Qualitative treatment of the Big Bang theory.
Cosmic microwave background radiation as evidence for the Big Bang.

Appreciation of the processes that are thought to have occurred immediately following the Big Bang;

Timeline for the creation of the Universe as we know it.
Falling temperature leading to Heavy particle, Light particle, Radiation and Matter 'eras'.
Possible fates of the Universe.

The questions to resolve: What is mass and why are some particles so much more massive than others? (the search for the Higgs particle); Why is there a matter universe? What is dark matter? Do gravitons exist?

The creation of matter from radiation and radiation from matter. Pair production: Photons, particles, antiparticles.
Annihilation of a particle and its antiparticle.
Appreciation of equivalence of mass and energy.
(NB Use of $E = mc^2$ is **not** required until A2.)
Appreciation of the problem raised by the existence of our matter universe.

How Science Works
In the search for a unifying theory, scientists are making new discoveries based on theoretical predictions and continue to work to confirm the discoveries of others.

Classification of particles:
Hadrons: Baryons (neutrons, protons) and mesons (pion, kaon).

Knowledge that: hadrons are subject to strong nuclear force.
protons are the only stable baryons.
other baryons eventually decay into protons.

In particular, the decay of a free neutron should be known.

Quarks and leptons; the building blocks of all matter.

Leptons: electron, muon, tau; their neutrinos and their antiparticles.
Knowledge that leptons are subject to the weak interaction.

Theoretical evidence, based on energy considerations, for the existence of neutrino leading to its discovery.

Quarks and anti-quarks:
Discovery of Quarks: evidence for the existence of an internal structure of protons and neutrons; qualitative study of deep inelastic scattering; comparison with Rutherford's scattering experiment.

Up (u) down (d) and strange (s) quarks only.
Properties of quarks: charge, baryon number and strangeness.

Strangeness as property that leads to particles with unusually long lifetimes.

Application of conservation laws for charge, lepton number, baryon number and strangeness to interactions.
Knowledge of the change of quark character in $beta^+$ and $beta^-$ decay.
(Baryon and lepton numbers will be provided in a data sheet or be given in questions.)

Appreciation that theory predicts a Higgs particle that is responsible for mass.

D Forces of nature
This is a brief section that serves to highlight the continuing search for a unifying theory of matter and examines some of the four forces of nature.

Concept of exchange particles to explain forces between particles.

Knowledge of the strong force, the electromagnetic force, the weak nuclear force and the gravitational force.

Photons as exchange particles for electromagnetic forces between charged particles.

W and Z particles as exchange particles for the weak force, responsible for radioactive decay.

Gluons as the exchange particle that leads to the strong force between quarks, protons and neutrons.

Gravitons postulated but (not yet detected) as the exchange particle for gravitational force between particles with mass.
(Feynman diagrams are **not** required.)

E Larger and larger

This section considers how cosmologists study objects at different distances from the Earth to develop theories about how the Universe was formed and how it is evolving.

How Science Works

When observing objects at large distances scientists are looking back in time and therefore studying the history of the Universe. Our knowledge and understanding is continually changing as a result of the observations. The study of the Universe is complementing the study of particle physics in Earth laboratories.

Collisions of electrons and atoms.
Ionisation and excitation.

Line spectra as evidence of transitions between discrete energy levels.

$hf = E_1 - E_2$

The electron-volt.

Evidence for star properties from spectra.

Classification by magnitude:
Relation between intensity and apparent magnitude.
Qualitative understanding of the difference between apparent and absolute magnitude.

Black body radiation: General shape of black body curves.
Wien's Law: $\lambda_{max} T = 0.0029 \text{ m K}$

Use of graphs of $P/\text{W m}^2$ against T/K to find total power emitted and compare power emitted by different stars.

Luminosity of a star as total power radiated.

Description of the main classes of stars:
O, B, A, F, G, K, M.
Classification by temperature

Stellar evolution:
Hertzsprung-Russell diagram: main sequence, dwarfs and giants.

Consideration of the life of a star similar to the Sun.

Doppler effect in sound and light limited to situations where the source is moving; use of approximation $-\frac{\Delta\lambda}{\lambda} = \frac{\Delta f}{f} = \frac{v}{c}$ and; Red-shift as evidence for expanding Universe.

Hubble law $v = Hd$
Age of the universe from the Hubble constant.

Quasars: most distant measurable objects; bright radio sources; show large optical red shifts; estimation of distance.
Galaxies: Mass of galaxy from orbital speed of stars (qualitative only) leading to existence of 'dark matter'.

3

3

3.2 Unit 2 PHYB2 Physics Keeps Us Going

3.2.1 Module 1, Moving People, People Moving

Society functions on the ability to move people and goods efficiently reliably. Sporting and participating, or being a spectator of sporting activities, is a feature of most people's leisure time.
This module considers how knowledge and understanding of forces and motion underpins everyday activities such as transport, where reliability is important, and activities such as record breaking in sport.

How do we describe the motion of an athlete or a vehicle? What affects the maximum speed of an athlete or a vehicle? What determines the trajectory and range of a ball? What energy changes occur during the motion? How does physics affect the design of vehicles and sports equipment? These and other questions will be tackled in this unit.

A How is motion described?
Study of the effect of wind on the movement of athletes and aircraft and water flow on the motion of boats.
Analysis of situations where one athlete aims to intercept another in sports such as rugby.

Vectors and scalars
Examples to include speed, velocity, mass and force/weight.

Addition of two vectors by scale drawing **and** calculation.

Calculation limited to two vectors at right angles.

Examples should relate to force and velocity vectors in particular.

Resolution of vectors into two components at right angles to each other.

B How do forces act?
Study of forces involved when rock climbing; balanced in gymnastics; skiing on a slope; a glider or parascender is towed.

Conditions for equilibrium of two or three forces acting at a point.
Use of scale drawing **or** resolved forces to solve problems.
Appreciation that a body is in equilibrium when at rest or when moving at constant velocity.

C How does motion change?
Description and analysis of the motion of cars/trains and planes accelerating and decelerating normally, when breaking in emergencies and in crashes.

How Science Works
Science involves the creation of mathematical models to describe and enable prediction of physics events. The '*suvat*' equations are one such example.

Shapes of s-t, v-t and a-t graphs for uniformly accelerated motion.
Understanding of rates of change with respect to time $v = \frac{\Delta s}{\Delta t}$ and $a = \frac{\Delta v}{\Delta t}$

Significance and calculation of gradient and area under s-t and v-t graphs for uniform and non-uniform motion.

Use of equations of motion for movement at constant velocity and acceleration; $v = u + at$
$s = \left(\frac{u+v}{2}\right)t$; $s = ut + \frac{1}{2}at^2$; $v^2 = u^2 + 2as$

D	**What makes motion change?** Study of motion under constant force in one dimension when diving or skiing. Study of motion of a ski jumper and motion of balls in ball sports to study motion in two dimensions. These are analysed quantitatively.	Use of $F=ma$ in situations where the mass is constant. Momentum = mv Impulse= change in momentum; $F\Delta t = \Delta(mv)$ (Relevant also in Section **E**) Impulse calculations using area under *F-t* graphs The forces perpendicular and at right angles to a body on an inclined plane due to its weight.
	Study of a skydiver with and without the parachute open and effects of air resistance on flight of a ball.	Independent effect of motion in horizontal and vertical directions. Experimental determination of *g* is **not** required.
	Study the factors affecting acceleration and maximum speed of cars from manufacturer data.	A qualitative study of situations in which acceleration is non-uniform. Knowledge that air resistance increases with speed. Explanation of effect on trajectories of projectiles.
	How Science Works Science and technology enables production of larger cars with more powerful engines. Comparison of fuel economy and the carbon dioxide output per kilometre are typical moral issues. Speed cameras make roads safer but some pressure groups question their increased use.	Explanation of the s-t; v-t and $a=t$ graphs for bodies moving in one dimension when air resistance and/or friction is present. Terminal velocity. Explanation of the maximum speed of vehicles and the factors that affect it.
	Study of how lift and drag forces affect take off and final motion of aircraft.	Lift and drag forces. Knowledge and applications of *lift* = *weight* and *thrust* = *drag* for constant velocity.

E	**What energy changes occur?** Looking at energy changes: examples from archery or throwing sports; bungee jumping; jumping and weight lifting.	Work, energy and power. Qualitative and quantitative application of energy conservation in a uniform gravitational field $\Delta E_p = mg\Delta h$ and $E_k = \frac{1}{2}mv^2$
	How Science Works Drug taking in sport can improve performance but may have long-term effects on health. There are ethical issues in gaining advantage through the use of performance enhancing drugs.	Work done = force × distance moved in the direction of the force = energy transferred $W = Fs\cos\theta$
	Study of the power developed by athletes in short bursts and over long periods.	Power = rate of doing work = rate of energy transfer $P = \frac{\Delta W}{\Delta t} = Fv$
	What use is elastic stored energy? A study of energy stored in towing cables and bars when a vehicle is being towed and the use of safety features in cars, such as crumple zones, seatbelts and air bags. Study of landing areas in sport and design of running shoes.	Elastic potential energy. Energy stored = area under force–extension graph. Energy stored = $\frac{1}{2}F\Delta L$, when $F \propto \Delta L$ Stiffness $k = \frac{F}{\Delta L}$ Explanation of the reduced force when momentum is dissipated over a longer time or energy over a longer distance.
	How Science Works Science has improved the safety for the driver of one vehicle whilst possibly increasing the risk for other road users and pedestrians. Conservation laws are used extensively in physics and are valid unless conflicting evidence is found in new experiments.	Energy conservation between energy source, kinetic energy and gravitational potential energy, elastic potential energy, energy to deform and internal energy of surroundings.

3.2.2 Module 2, Energy and the Environment

All nations are faced with the problem of satisfying increasing energy demands and the effect this has on the fate of the planet and future generations. Where does our energy come from? What are the options for the future? What are the consequences of our use of energy? How do we use energy and why do we need so much? How can we use energy more efficiently? These questions will be tackled in this unit. Electrical energy is a particularly convenient form on which much of our practical technologies are based. The unit focuses on some of the rules associated with our use of electricity.

A **Where does our energy come from and where does it go?**
Study of the common sources of energy generated and how it is used in the United Kingdom and internationally. The work includes a study of the use of solar, carbon-based and nuclear resources and is made quantitative through the use and interpretation of Sankey diagrams.

Ability to compare critically, data from the UK and other countries.

Knowledge of the relative amounts of energy available from non-renewable sources at a national and international level.

Appreciation that solar energy may be used directly or from secondary sources such as wind and tides (see also Section **D** – Sources of renewable energy).

Knowledge of the relative amounts of energy currently generated by different sources in the UK.

How Science Works
Imbalance in the use of energy between individuals and nations is an ethical issue. Manufacturing material goods requires the use of energy and leads to a relationship between economic growth and energy use.

Knowledge of how energy is used at an individual, national and international level.

Use and interpretation of Sankey diagrams representing energy changes.

B **Impact of energy conversion**
Study of the on-going debate that centres around global warming and its effects.
The study builds on the GCSE experience, developing an understanding of some of the physics principles that are involved in explaining the cause of global warming and its effects.

Factors that affect the rate at which the temperature of the Earth rises.

Knowledge of the major regions of the electromagnetic spectrum: their approximate wavelengths and frequencies and, where appropriate, an appreciation of their possible effects on humans.

Understanding of the 'greenhouse' effect and that this is affected by CO_2 levels in the atmosphere.

How Science Works
Science, through the exploitation of its application during the industrial revolution and subsequently, has contributed to global warming. Scientists explain how global warming occurs, inform decision-makers of consequences and advise on changes to limit the effect.

Knowledge of the need for balance between energy inflow from the Sun and energy re-radiation from the Earth (links to next Section).
Recognition that 'global warming' implies a lack of balance and that equilibrium may return at a higher temperature.
Understanding that wavelengths are converted into the near infrared in the atmosphere.

Balance of emission/absorption – comparison with other planets.

Use of graphs of P/Wm^2 against T/K to compare power losses.
Wien's law $\lambda_{max}T$ = *constant*

Rising sea level due to melting ice caps.
Appreciation that melting of ice on land increases sea level but melting icebergs do not.

Principle of flotation and Archimedes' principle.
Density $\rho = \frac{m}{V}$, (calculations required).

C Using electrical energy

Study of the way electrical energy is stored in storage cells and used in motors, heaters and lamps. The study includes appreciation of how each use ultimately leads to conversion of all the energy to produce heating.

How Science Works
Scientists explain macroscopic phenomena using microscopic models.

Charge, current and potential difference.
Electric current as rate of flow of charge.

$$I = \frac{\Delta Q}{\Delta t}$$

Potential difference defined as the work done per coulomb of charge transferred between two points.

Definition of resistance; the ohm.

Definition of the volt as 1 joule per coulomb

Power dissipation $P = IV;\ P = I^2R;\ P = \frac{V^2}{R}$

Energy = Pt; kW h and an appreciation of current cost.

The behaviour of ohmic and non-ohmic conductors including a practical investigation of filament lamp and ntc thermistor.

Thermistor as a device for use in controlling temperature.
A simple microscopic explanation of conduction in solids, liquids and gases; resistance, how thermal energy is generated when charge flows, and how resistance changes with temperature for metals and ntc thermistors.

Resistances in series and parallel; calculations of the total resistance of circuits with series and/or parallel components

$$R = R_1 + R_2 + R_3 + \ldots;\quad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

Current conserved at a junction.
Total pd = sum of pd across series resistors.
Electrical variations produced by potential divider systems and on-off switches.
Use of potential divider to control voltage comparison with use of variable resistor.
Link with use in microphone/loudspeaker circuit to act as volume and balance control.
Electromotive force and internal resistance and their measurement

$$\varepsilon = \frac{E}{Q}$$

$$\varepsilon = I(R + r)$$

How Science Works
Superconductors benefit society in providing high magnetic field strengths and low loss conductors. The discovery of high temperature superconductors would result in further benefits.

Terminal potential difference

Electrical resistivity $\rho = \frac{RA}{L}$

Superconductivity

Energy lost in transmission of electrical energy and how this is reduced in the national grid.

Energy distribution: the desirability of transmitting electrical energy using low resistance cable at a high potential difference and low current.
Appreciation of the role of ac transformers.
(No calculations are required.)

D Sources of renewable energy

Study of the wide range of renewable energy sources. The study will include a general understanding of some of the techniques available for energy conversion and involve quantitative analysis of some sources

How Science Works
The energy available from different sources and from individual devices informs decision-making when deciding how energy should be produced in future. Pressure groups may use science to promote their cause, extracting those parts that support their view whilst ignoring other parts.

Knowledge of at least one advantage and one disadvantage for each of the following sources; solar power, wind- wave conversions, tides, HEP, pumped storage, and wind turbine conversions.

Intensity of power from the Sun $I = \frac{P}{A}$

Inverse square law for a point source $I = \frac{P}{4\pi r^2}$
(links to Unit 2)

Energy conversion using solar cells.
Role of Sun in producing power from wind and tides.
Estimation of energy in a wave (links to Unit 1 wave ideas).
PE ↔KE conversions and power considered in relation to tidal barrages, hydroelectric and pumped storage systems.
Use and derivation of

Power available from wind = $\frac{1}{2}\pi r^2 \rho v^3$

3

E Efficient use of energy

A study of energy use in the home and how energy can be conserved. The study includes the storage of energy, home insulation and double glazing, and comparisons between conventional filament lamps and modern energy-efficient fluorescent types.

How Science Works
Science predicts and explains ways in which energy is wasted and that science informs decision-making on house design and modifications that reduce energy needs.

Use of rechargeable cells.

Efficiency including the calculation of overall efficiency of a multistage process.

Efficiency of energy conversion in the electrical generators, lamps and motors.

Comparison of efficiency for a filament lamp and an energy-efficient lamp.

Energy lost by natural and forced convection: Newton’s law of cooling under forced convection; concept of half-cooling time (qualitative links to GCSE knowledge of radioactive decay model).

Factors affecting thermal energy transfer by conduction and radiation.

Temperature gradient, conductivity of material, cross-sectional area.

U-values; Range of *U*-values of common building materials.
Rate of energy transfer = $UA\Delta\theta$
Use to calculate total heat loss for parallel surfaces only.

3.3 Unit 3 Investigative and Practical Skills in AS Physics

Candidates should carry out experimental and investigative activities in order to develop their practical skills. Experimental and investigative activities should be set in contexts appropriate to, and reflect the demand of, the AS content. These activities should allow candidates to use their knowledge and understanding of Physics in planning, carrying out, analysing and evaluating their work.

The specifications for Units 1 and 2 provide a range of different practical topics which may be used for experimental and investigative skills. The experience of dealing with such activities will develop the skills required for the assessment of these skills in the Unit. Examples of suitable experiments that could be considered throughout the course will be provided in the Teachers' Resource Bank.

The investigative and practical skills will be internally assessed through two routes.

- Route T – Investigative and Practical skills (Teacher assessed)
- Route X – Investigative and Practical skills (Externally Marked)

Route T – Investigative and Practical skills (Teacher assessed)

The assessment in this route is through two methods.

- Practical Skills Assessment (PSA)
- Investigative Skills Assignment (ISA)

The PSA will be based around a centre assessment throughout the AS course of the candidate's ability to follow and undertake certain standard practical activities.

The ISA will require candidates to undertake practical work, collect and process data and use it to answer questions in a written test (ISA test). See Section 3.8 for PSA and ISA details.

It is expected that candidates will be able to use and be familiar with 'standard' laboratory equipment which is deemed suitable at AS level, throughout their experiences of carrying out their practical activities.

This equipment might include:

Electric meters (analogue or digital), metre rule, set squares, protractors, vernier callipers, micrometer screwgauge (zero errors), an electronic balance, stopclock or stopwatch, thermometer (digital or liquid-in-glass), newtonmeters.

Candidates will not be expected to recall details of experiments they have undertaken in the written units 1 and 2. However, questions in the ISA may be set in experimental contexts based on the units, in which case full details of the context will be given.

Route X – Investigative and Practical skills (Externally Marked)

The assessment in this route is through a one off opportunity of a practical activity.

The first element of this route is that candidates should undertake five short AQA set practical exercises throughout the course, to be timed at the discretion of the centre. Details of the five exercises will be supplied by AQA at the start of the course. The purpose of these set exercises is to ensure that candidates have some competency in using the standard equipment which is deemed suitable at this level. No assessment will be made but centres will have to verify that these exercises will be completed.

The formal assessment will be through a longer practical activity. Details of this activity will be provided every March. The activity will require candidates to undertake practical work, collect and process data and use it to answer questions in a written test. The activity will be made up of two tasks, followed by a written test. Only one activity will be provided every year.

Across both routes, it is also expected that in their course of study, candidates will develop their ability to use IT skills in data capture, data processing and when writing reports. When using data capture packages, they should appreciate the limitations of the packages that are used. Candidates should be encouraged to use graphics calculators, spreadsheets or other IT packages for data analysis and again be aware of any limitations of the hardware and software. However, they will not be required to use any such software in their assessments through either route.

The skills developed in course of their practical activities are elaborated further in the *How Science Works* section of this specification (see section 3.7).

In the course of their experimental work candidates should learn to:

- demonstrate and describe ethical, safe and skilful practical techniques
- process and select appropriate qualitative and quantitative methods
- make, record and communicate reliable and valid observations
- make measurements with appropriate precision and accuracy
- analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

3

3.4 Unit 4 PHYB4 Physics Inside and Out

3.4.1 Module 1, Experiences Out of this World

This module is about how physics is used to send probes and astronauts into space and the problems that need to be overcome in order to do this. It includes the ideas of free-fall and apparent weightlessness of capsules in orbital motion.

A Attracted to the Earth
A study of the forces and motion of bodies due to Earth and atmosphere including satellite orbits.

How Science Works
Discuss how it may be argued that the costs of spaceflight are too great and that the money could be better spent in other ways. Discuss also how the development of technology to enable space flight has produced benefits to our everyday lives.

The effect of gravity in producing weight.
Gravitational field strength; $w = mg$
The apparent weight in lifts.

$ma = R \pm mg$ in lift: development of concepts met at AS.

Spherical bodies moving through a viscous medium on Earth – Stokes' law (at terminal velocity only).
$mg = 6\pi\eta r v_t$

Newton's gravitational law $F = -\frac{GMm}{r^2}$

Inverse square variation of g with separation from the centre of the Earth for positions above the Earth's surface.
Variation of g for distances less than the Earth's radius are **not** required.

Angular velocity $v = r\omega$

Centripetal force as $m\omega^2 r$ or $\frac{mv^2}{r}$

Gravitation providing the centripetal force to keep us on the Earth (or in orbit around the Earth).

Reaction and weight. Weightlessness.

B Leaving the Earth
A study of the energy involved in spaceflight.

Candidates should be able to sketch field lines and equipotential surfaces and interpret diagrams of these.

Gravitational potential and gravitational potential energy
Change in potential = area under the graph of g against r.

$$\Delta E_p = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Consideration of energy transfers involved during launch and return.
Energy needed to escape (e.g. from the Earth).
Instantaneous kinetic energy that would result in needing to cause object to reach infinity leading to escape velocity $v_{esc} = \sqrt{\frac{2GM}{R}}$

C It is rocket science
A study of how the space shuttle is propelled into space including ideas of thrust, impulse and relationship with change of momentum.

Forces acting on rockets – thrust, weight, and aerodynamic forces, comparison with forces on aeroplanes.

Momentum = mv

$Ft = mv - mu$ and link with Newton's third law.

Conservation of linear momentum.

The rocket equation $v_f = v_e \ln(m_0 / m)$ applied in free space only – related graphs (proof of the equation is **not** required).

Concept of payload: fuel ratio.

Understanding of how thrust is produced. Development of rocket fuels – reaction of propellants to produce hot expanding gases (the working fluid) in combustion chamber.

How Science Works
Discuss how no process of conversion of energy into a useful form can be 100% efficient and that ultimately the energy is all internal energy. Return to the problem of global warming.

Ideal gas equation: $pV = nRT$ applied to the expansion of gases.

Definition of pressure = F/A

The first law of thermodynamics applied to gas produced in a rocket.

$\Delta U = Q + W$

Work done expanding gases $p\,\Delta V$

Energy released when a gas is compressed and then expands to atmospheric pressure.

3

3.4.2 Module 2, What Goes Around Comes Around

Theme parks continue to excite both young and old with the thrills of freefall, looping the loop or simply spinning round and round. In this module energy and momentum conservation are considered in relation to theme park rides.

A Back and Forth and Up and Down
Repetitive rides using simple harmonic motion exemplified by the swing boat, pirate ship and other pendulum or vertically oscillated rides such as the reverse bungee (catapult bungee or ejector seat). Roller coaster limited to track of sinusoidal profile.

Simple harmonic motion

$a = -(2\pi f)^2 x$

$x = A \cos 2\pi ft$

Maximum acceleration = $(2\pi f)^2 A$

Graphical treatment with velocity as gradient of the displacement–time graph and acceleration as the gradient of a velocity–time graph.

Maximum speed = $2\pi fA$

Mass-spring system with $T = 2\pi \sqrt{(m/k)}$

Simple pendulum with $T = 2\pi \sqrt{(l/g)}$

How Science Works
Discuss how we balance the enjoyment we get out of such activities against the risks. Analyse whether a particular 'ride' is safe.

Energy considerations, maximum and minimum kinetic and potential energy compared with total energy including graphical treatment. Variations with time and position.

Damping and resonance.

B **Round and Round**
Rides involving uniform circular motion exemplified by: the rotor ('gravitron') ferris wheel (big wheel), chair-o-planes ('swing carousel') orbiter etc.

Requirement of centripetal force – provided by normal reaction, weight, tension or components of these forces.

Use of $F = m\omega^2 r$ or $\dfrac{mv^2}{r}$
(links with Section **C**)

C **Spinning faster and faster**
Rides for which the moment of inertia is significant such as the Waltzer, looping rides with asymmetrical distribution of mass. Accelerating the rides to their maximum angular speeds.

Angular momentum = $I\omega$
Angular kinetic energy = $\frac{1}{2} I\omega^2$

The effect of torque on angular momentum. Moment of inertia defined as ratio of torque to angular acceleration $I = T/\alpha$; moment of inertia dependent on mass and mass distribution.

Angular acceleration defined as the rate of change of angular velocity $\alpha = \Delta\omega/\Delta t$

Conservation of angular momentum and equations of motion for uniform angular acceleration treated by analogy with uniformly accelerated linear motion.

3

3.4.3 Module 3, Imaging the Invisible

This module is about how physics is used to investigate things that cannot be seen directly with the eye. The first sections are a study of the techniques available to geophysicists and archaeologists in the search for new mineral resources and buried remains. In the final section the techniques available to doctors for imaging organs inside the body are studied.

A **Gravity surveys**
A study of how variations of gravitational field strength is used to find new ore bodies containing useful minerals.

Definition of gravitational field strength
$g = \dfrac{F}{m}$

Newton's gravitational law $F = -\dfrac{GMm}{r^2}$

How Science Works
The costs of finding new sources, and the need for recycling, of mineral resources in the light of dwindling natural supplies with increasing demands.

Factors affecting local variations in g; typical magnitude of variations. Use of local variations to identify ores.

Measurement techniques; g using pendulums and mass spring systems.
The gal = 0.01 m s^{-2}

B	**Magnetic surveys** A study of the how magnetic field strength variations are used to detect buried objects and the techniques used.	Definition of magnetic flux density using $F = BIl$ Factors affecting flux density produced by current in wires and coils. (Knowledge of formulae is **not** required.) Concept of flux $\Phi = BA$ and flux linkage $N\Phi = BAN$ Faraday's and Lenz's laws Magnitude of induced emf $\varepsilon = N\dfrac{\Delta\Phi}{\Delta t}$ Eddy currents. Measurement of flux density using induced emf. Factors affecting local variations in magnetic flux density; typical magnitude of variations. Use of local variations to identify buried objects. Principles of operation of proton magnetometer (see also MRI scanner Section 3.4.3D). Principle of operation of a metal detector.
C	**Resistivity and seismic surveys** In this section electrical and wave topics studied in AS and principles of electromagnetism are applied in geophysics and archaeology.	Geophone operation – schematic diagram and explanation of the production of induced emf used to trigger timers in seismic surveys.
	How Science Works Discuss how the techniques used for such surveys are also used to predict and warn of earthquakes and possible tsunami incidents.	Review of how concepts in waves and electricity learned in AS are used in mineral exploration.

3

D	**Medical diagnosis without surgery** A study of the techniques of X-ray, ultrasound, MRI scanners and endoscopy.	Principles of X-rays. Production: continuous and line spectrum. Properties of electron beams. Energy gained by electron = eV Electron gun equation $eV = \frac{1}{2}mv^2$ Maximum photon energy $hf = eV$
	How Science Works The benefits and risks of exposure to radiation and strong magnetic fields should be discussed during this section.	Properties of X-rays and uses in diagnosis. Use of contrast medium and image intensifier. Safety precautions. Principles of ultrasound. Echoes. Typical wavelengths of ultrasound and how this affects resolution of the images. Image types. Comparison of advantages and disadvantages of ultrasound and X-rays. Principle of the MRI scanner: use of superconducting magnets. Alignment of spinning protons in the field, precession. Use of 'gradient' field coils to cause resonant change of spin state in a small region. Detection of relaxation and computer build up of final image. Advantages and disadvantages of MRI compared with X-rays and ultrasound. Principles of endoscope: recall from AS: refraction of light and total internal reflection; Snell's law. Fibre optic cable: use of non-coherent bundle for illumination and coherent bundle for imaging. Explanation of image production using a digital camera. (Charged coupled devices)

3.5 Unit 5 PHYB5 Energy Under the Microscope

3.5.1 Module 1, Matter under the Microscope

How can macroscopic quantities such as temperature and pressure be explained by the molecular model of matter? The context for study in this module is the heat engine exemplified by steam and internal combustion engines.

A Power from engines

Study of the behaviour of an ideal gas contained in a cylinder enclosed by a piston exemplified by an engine cylinder and how its behaviour is explained by the kinetic theory.

Revision of evidence for atoms and molecules from AS.
Brownian motion.
Kinetic theory model for a gas.

Assumptions and use of formula (no derivation required)

$pV = \frac{1}{3}Nm\langle c^2\rangle$

How Science Works
Scientists explain macroscopic phenomena using microscopic models. Scientists develop mathematical rules or laws to describe phenomena. The law is then used to predict effects of changes.

Kinetic energy of gas molecules and relation to Boltzmann constant $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

Qualitative explanation of pressure and effect of volume and temperature changes on pressure

$pV = NkT$

Avogadro constant.

Concept of absolute zero.

B Heating, cooling and working

The cooling of an engine by means of the flow of a fluid should be studied. Continuous flow heating and thermal efficiency.

Internal energy U.

Specific heat capacity $E = mc\Delta\theta$

Engine cooling using continuous flow of fluid.

Power input or output = $\frac{\Delta m}{\Delta t}c\Delta\theta$

The energy cycle should be exemplified by isothermal and adiabatic changes related to the first law of thermodynamics.

The zeroth law of thermodynamics.
First law of thermodynamics: raising internal energy by heating and working $\Delta U = Q + W$
Q defined by energy input to system due to difference in temperatures.
W defined by work done on the system.

How Science Works
Discuss how no process of conversion of energy into a useful form can be 100% efficient and that ultimately energy becomes internal energy, raising temperature. Return to the problem of global warming.

Work done = $p\Delta V$

Basic understanding of what happens at each stage in a four-stroke internal combustion engine and how a number of cylinders is used to maintain a steady driving force.

Work done in engine cycles including the Carnot cycle.

Efficiency of engines.
Maximum Efficiency = $\frac{T_H - T_C}{T_H}$

3

C **Arrow of time**
A brief study of the natural trend of events based on increasing entropy.
Gas in cylinder and surrounding representing a closed system.

Concept of entropy.
Idea of entropy as number of ways of distributing energy.
Natural tendency to increasing disorder: for spontaneous processes number of ways of distributing energy in system increases.

Entropy change defined by $\Delta S = \frac{Q}{T}$

3.5.2 Module 2, Breaking Matter Down

How do physicists visualise the structure of matter? The context of this module is the tools used to produce high energy particles using electric and magnetic fields and how the properties of these particles are determined.

3

D **Accelerators and VDU**
The mass spectrometer, linear accelerator, cyclotron and synchrotrons including an overview of the features of Large Hadron Collider. The acceleration and deflection of charged particles in accelerators and cathode ray tubes.

Electric field; ions.
Uniform electric fields $E = \frac{V}{d} = \frac{F}{Q}$

Calculations of forces between charges using

Coulomb's law $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$

Qualitative treatment of thermionic emission.
Accelerating particles; Electron gun

$eV = \frac{1}{2}mv^2$

Bending beams using magnetic fields

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

How Science Works
Scientists develop models of nuclear structure by examining what goes in and what comes out of an interaction.

Balanced fields in velocity selector $EQ = BQv$

Cyclotron frequency = $\frac{BQ}{2\pi m}$

How Science Works
Scientists modify or produce new theories when events occur that are inexplicable using existing theories. Here classical physics breaks down at speeds approaching the speed of light necessitating modification given by relativistic mechanics.

Introduction to relativity. The effects of increasing mass on the operation of accelerators such as the Large Hadron Collider (LHC) and length contraction/time dilation on the decay of muons should be discussed.

Use of $l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$ $m = \frac{m_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$

and $t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$

3.5.3 Module 3, Energy from the Nucleus

How can matter/energy considerations lead to the generation of energy and how safe are the uses of nuclear materials? The context for this module is the peaceful use of both spontaneous and stimulated nuclear decay and a consideration of nuclear fusion. Throughout the module the benefits and risks of the use of radioactivity and nuclear energy are studied.

A Isotopes in medicine

The uses of radioactive isotopes in diagnosis and treatment of diseases in medicine.

Review of evidence for structure of nucleus (from AS).
Proton number Z and nucleon number A. Familiarity with the terms nuclide and isotope.

Nuclear stability and instability; α, β^-, β^+ and γ radiations.
Changes in Z and A in α and β^- and β^+ decay.

Nuclear changes in decay.
Nuclear equations.

Ionisation.
Nature of ionising particles
- description
- inverse-square law for γ absorption
- $I = I_0 e^{-\mu x}$: ½ value thickness; factors affecting μ.

Activity of radioactive sources; Becquerel.

How Science Works
Development of a mathematical model from the statistical behaviour of a large number of random events enabling prediction of changes over a period of time.

Modelling with constant decay probability leading to exponential decay.

Quantitative use of $N = N_0 e^{-\lambda t}$ (no proof required).

Recognition that $dN/dt = -\lambda N$ represents radioactive changes.

Diagnostic and therapeutic use of iodine-131 (^{131}I); technetium-99m (^{99m}Tc) used as an example of a radioactive label. The choice of α, β and γ emitter to perform a particular function.

Idea of half-life, calculations and use of half-life, relationship between half-life and decay constant.

How Science Works
Accelerators initially designed for scientific research are now the sources of radioactive materials for use in medicine and industry.

Physical, biological and effective half-lives in medicine, calculations involving these quantities.

3

B	**Keeping the heart beating** The use of capacitors to control the timing of pulses in heart pacemakers and the use of radioisotopes for thermoelectric generators to provide the energy for the pulses. The factors affecting the useful lifetime of the device.	Capacitors Formal analogy between capacitor discharge and radioactive decay. Definition of capacitance $Q = CV$ Use to store energy and as a 'timing' component. Charge and discharge curves. Quantitative work for discharge only $Q = Q_0 e^{-t/CR}$
C	**Where nuclear energy comes from** A study of the instability in the nucleus and how changes in the nucleus can lead to the release of energy as the nucleus moves towards greater stability.	The graph of neutron number N against proton number Z. Appreciation that when a nucleus decays the residual nucleus is closer to the line of stability and that mass is reduced in the process. Binding energy, binding energy per nucleon, mass defect, atomic mass units and conversions; use of the graph of binding energy per nucleon against nucleon number.
	How Science Works Modification to understanding of energy in view of loss of mass in nuclear reactions and the increased mass in the creation of new particles.	$\Delta E = \Delta mc^2$ applied to nuclear processes. Appreciation that $\Delta E = \Delta mc^2$ applies to all energy changes. Simple calculations relating mass difference to energy change.
D	**Physics of fission** A consideration of the mechanisms involved in controlling and moderating a pressure water reactor as an example of a nuclear reactor. How Science Works Scientists have to inform decision-makers as to the most beneficial type of reactor. The advantages and disadvantages of different types of reactor have to be considered.	Descriptions of fission processes: induced fission by neutron stimulation. Nuclear reactor physics: moderation including simple mechanical model of moderation by elastic collision control mechanisms description of reactor limited to pressurised water reactor design means of extracting energy (coolants; link to Unit 5 Module 1) concept of absorption and fission cross-sections. (No calculations of absorption cross-section required.)

3

E	**Fusion – energy for the future?** A look at how imitating the fusion processes in the stars could provide the Earth's future energy requirements.	Descriptions of fusion processes. Calculations of energy available for fusion reactions. Calculation of closest distance of approach of two nuclei from $E_k = E_p = \frac{Qq}{4\pi\varepsilon_0 r}$ and hence estimate of temperature necessary for two nuclei to fuse.
	How Science Works Understanding of stellar processes helps scientists to develop solutions to energy problems on Earth.	Knowledge of hydrogen cycle and the carbon cycle in the production of solar energy. Description of the production of plasma and the problems involved in maintaining fusion reactions in a terrestrial fusion reactor exemplified by an overview of the operation of the Joint European Torus. Benefits and problems surrounding terrestrial fusion.
F	**Perceptions of risk** An overview of the public perception of risk and how risks are minimised in the nuclear industry and in medical applications.	Consideration of risk in everyday life. Quantitative treatment of risk. Risk in nuclear engineering, minimising the risk. Risk in medical physics- balancing risks in treatment of illness.
	How Science Works The problems of public safety and how dangers are balanced against the benefits is inherent in the topic. The importance of public understanding of science in making rational judgment of acceptable risk.	Worker protection techniques (qualitative only). Film badge/radiation monitors.

3

3.6 Unit 6 Investigative and Practical Skills in A2 Physics

Candidates should carry out experimental and investigative activities in order to develop their practical skills. Experimental and investigative activities should be set in contexts appropriate to, and reflect the demand of, the A2 content. These activities should allow candidates to use their knowledge and understanding of Physics in planning, carrying out, analysing and evaluating their work.

The specifications for Units 4 and 5 provide a range of different practical topics which may be used for experimental and investigative skills. The experience of dealing with such activities will develop the skills required for the assessment of these skills in the Unit. Examples of suitable experiments that could be considered throughout the course will be provided in the Teachers' Resource Bank.

The investigative and practical skills will be internally assessed through two routes.

- Route T – Investigative and Practical skills (Teacher assessed)
- Route X – Investigative and Practical skills (Externally Marked)

Route T – Investigative and Practical skills (Teacher assessed)

The investigative and practical skills will be centre assessed through two methods.

- Practical Skills Assessment (PSA)
- Investigative Skills Assignment (ISA).

The PSA will be based around a centre assessment throughout the A2 course of the candidate's ability to follow and undertake certain standard practical activities.

The ISA will require candidates to undertake practical work, collect and process data and use it to answer questions in a written test (ISA test). See Section 3.8 for PSA and ISA details.

It is expected that candidates will be able to use and be familiar with more 'complex' laboratory equipment or techniques which is deemed suitable at A2 level, throughout their experiences of carrying out their practical activities.

Reference made to more complex equipment/techniques might include:

Oscilloscope, travelling microscope, other vernier scales, spectrometer, data logger, variety of sensors, light gates for timing, ratemeter or scaler with GM tube, avoiding parallax errors, timing techniques (multiple oscillations).

Candidates will not be expected to recall details of experiments they have undertaken in the written units 4 and 5. However, questions in the ISA may be set in experimental contexts based on the units, in which case full details of the context will be given.

Route X – Investigative and Practical skills (Externally Marked)

The assessment in this route is through a one off opportunity of a practical activity.

The first element of this route is that candidates should undertake five short AQA set practical exercises throughout the course, to be timed at the discretion of the centre. Details of the five exercises will be supplied by AQA at the start of the course. The purpose of these set exercises is to ensure that candidates have some competency in using the standard equipment which is deemed suitable at this level. No assessment will be made but centres will have to verify that these exercises will be completed.

The formal assessment will be through a longer practical activity. Details of this activity will be provided every March. The activity will require candidates to undertake practical work, collect and process data and use it to answer questions in a written test. The activity will be made up of two tasks, followed by a written test. Only one activity will be provided every year.

Across both routes, it is also expected that in their course of study, candidates will develop their ability to use IT skills in data capture, data processing and when writing reports. When using data capture packages, they should appreciate the limitations of the packages that are used. Candidates should be encouraged to use graphics calculators, spreadsheets or other IT packages for data analysis and again be aware of any limitations of the hardware and software. However, they will not be required to use any such software in their assessments through either route.

The skills developed in course of their practical activities are elaborated further in the *How Science Works* section of this specification (see section 3.7).

In the course of their experimental work candidates should learn to:

- demonstrate and describe ethical, safe and skilful practical techniques
- process and select appropriate qualitative and quantitative methods
- make, record and communicate reliable and valid observations
- make measurements with appropriate precision and accuracy
- analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

3.7 How Science Works

How Science Works is an underpinning set of concepts and is the means whereby students come to understand how scientists investigate scientific phenomena in their attempts to explain the world about us. Moreover, *How Science Works* recognises the contribution scientists have made to their own disciplines and to the wider world.

Further, it recognises that scientists may be influenced by their own beliefs and that these can affect the way in which they approach their work. Also, it acknowledges that scientists can and must contribute to debates about the uses to which their work is put and how their work influences decision-making in society.

In general terms, it can be used to promote students' skills in solving scientific problems by developing an understanding of:

- the concepts, principles and theories that form the subject content
- the procedures associated with the valid testing of ideas and, in particular, the collection, interpretation and validation of evidence
- the role of the scientific community in validating evidence and also in resolving conflicting evidence.

As students become proficient in these aspects of *How Science Works*, they can also engage with the place and contribution of science in the wider world. In particular, students will begin to recognise:

- the contribution that scientists, as scientists, can make to decision-making and the formulation of policy
- the need for regulation of scientific enquiry and how this can be achieved
- how scientists can contribute legitimately in debates about those claims which are made in the name of science.

An understanding of *How Science Works* is a requirement for this specification and is set out in the following points which are taken directly from the *GCE AS and A Level subject criteria for science subjects*. Each point is expanded in the context of Physics. The specification references given illustrate where the example is relevant and could be incorporated.

A	**Use theories, models and ideas to develop and modify scientific explanations** Scientists use theories and models to attempt to explain observations. These theories or models can form the basis for scientific experimental work. Scientific progress is made when validated evidence is found that supports a new theory or model. Candidates should use historical examples of the way scientific theories and models have developed and how this changes our knowledge and understanding of the physical world. *Examples in this specification include:* • *Unit 1, Module 2: From Quarks to Quasars (Section A – Smaller and smaller)* In this section candidates study the historical development of the model for the microstructure of matter. Candidates will consider how previously held theories have been changed by new discoveries and whether our existing theories are equally tenuous. • *Unit 5, Module 1: Matter Under the Microscope (Section A – Power from engines)* Candidates will learn that scientists explain macroscopic phenomena using microscopic models. Mathematical rules or laws are then developed to describe phenomena. These rules and laws are then used to predict effects of changes.
B	**Use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas** Scientists use their knowledge and understanding when observing objects and events, in defining a scientific problem and when questioning their own explanations or those of other scientists. Scientific progress is made when scientists contribute to the development of new ideas, materials and theories. Candidates will learn that: • a hypothesis is an untested idea or theory based on observations • predictions from a hypothesis or a theory need to be tested by experiment • if a reliable experiment does not support a hypothesis or theory, the hypothesis or theory must be changed. *Examples in this specification include:* • *Unit 3, Investigative and Practical skills* There are many opportunities permeating throughout this unit. • *Unit 6, Investigative and Practical skills* There are many opportunities permeating throughout this unit.

3

C	**Use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems**
	Observations ultimately lead to explanations in the form of hypotheses. In turn, these hypotheses lead to predictions that can be tested experimentally. Observations are one of the key links between the 'real world' and the abstract ideas of science. Once an experimental method has been validated, it becomes a protocol that is used by other scientists. ICT can be used to speed up, collect, record and analyse experimental data. Candidates will know how to: • plan or follow a given plan to carry out an investigation on topics relevant to the specification • identify the dependent and independent variables in an investigation and the control variables • select appropriate apparatus and methods, including ICT, to carry out reliable experiments relevant to topics in the specification • choose measuring instruments according to their sensitivity and precision.
	Examples in this specification include: • *Unit 3, Investigative and Practical skills* There are many opportunities permeating throughout this unit. • *Unit 6, Investigative and Practical skills* There are many opportunities permeating throughout this unit.
D	**Carry out experimental and investigative activities, including appropriate risk management, in a range of contexts**
	Scientists perform a range of experimental skills that include manual and data skills (tabulation, graphical skills etc). Scientists should select and use equipment that is appropriate when making accurate measurements and should record these measurements methodically. Scientists carry out experimental work in such a way as to minimise the risk to themselves, to others and to the materials, including organisms, used. Candidates will be able to: • follow appropriate experimental procedures in a sensible order • use appropriate apparatus and methods to make accurate and reliable measurements • identify and minimise significant sources of experimental error • identify and take account of risks in carrying out practical work.
	Examples in this specification include: • *Unit 3, Investigative and Practical skills* There are many opportunities permeating throughout this unit. • *Unit 6, Investigative and Practical skills* There are many opportunities permeating throughout this unit.

E	**Analyse and interpret data to provide evidence, recognising correlations and causal relationships**
	Scientists look for patterns and trends in data as a first step in providing explanations of phenomena. The degree of uncertainty in any data will affect whether alternative explanations can be given for the data. Anomalous data are those measurements that fall outside the normal, or expected, range of measured values. Decisions on how to treat anomalous data should be made only after examination of the event. In searching for causal links between factors, scientists propose predictive theoretical models that can be tested experimentally. When experimental data confirm predictions from these theoretical models, scientists become confident that a causal relationship exists. Candidates will know how to: • tabulate and process measurement data • use equations and carry out appropriate calculations • plot and use appropriate graphs to establish or verify relationships between variables • relate the gradient and the intercepts of straight line graphs to appropriate linear equations.
	Examples in this specification include: • *Unit 3, Investigative and Practical skills* There are many opportunities permeating throughout this unit. • *Unit 6, Investigative and Practical skills* There are many opportunities permeating throughout this unit.
F	**Evaluate methodology, evidence and data, and resolve conflicting evidence**
	The validity of new evidence, and the robustness of conclusions that stem from them, is constantly questioned by scientists. Experimental methods must be designed adequately to test predictions. Solutions to scientific problems are often developed when different research teams produce conflicting evidence. Such evidence is a stimulus for further scientific investigation, which involves refinements of experimental technique or development of new hypotheses. Candidates will be able to: • distinguish between systematic and random errors • make reasonable estimates of the errors in all measurements • use data, graphs and other evidence from experiments to draw conclusions • use the most significant error estimates to assess the reliability of conclusions drawn.
	Examples in this specification include: • *Unit 3, Investigative and Practical skills* There are many opportunities permeating throughout this unit. • *Unit 6, Investigative and Practical skills* There are many opportunities permeating throughout this unit.

<table>
<tr><td rowspan="2">G</td><td>Appreciate the tentative nature of scientific knowledge</td></tr>
<tr><td>Scientific explanations are those that are based on experimental evidence which is supported by the scientific community.

Scientific knowledge changes when new evidence provides a better explanation of scientific observations.

Candidates will be able to understand that scientific knowledge is founded on experimental evidence and that such evidence must be shown to be reliable and reproducible. If such evidence does not support a theory the theory must be modified or replaced with a different theory. Just as previous scientific theories have been proved inadequate or incorrect, our present theories may also be flawed.</td></tr>
<tr><td></td><td>Examples in this specification include:

• Unit 1, Module 2: From Quarks to Quasars (Section A – Smaller and smaller)
How the “plum pudding” model of the atom has evolved through experimentation to give scientists their current understanding of the constituents of an atom.

• Unit 5, Module 2: Breaking Matter Down (Section D – Accelerators and VDU)
Candidates should be aware that, during experimentation when events occur which can not be explained using current scientific theories, scientists modify existing theories, or produce new theories to explain their findings. An example of this would be when classical physics breaks down at speeds approaching the speed of light necessitating modification given by relativistic mechanics.</td></tr>
<tr><td rowspan="2">H</td><td>Communicate information and ideas in appropriate ways using appropriate terminology</td></tr>
<tr><td>By sharing the findings of their research, scientists provide the scientific community with opportunities to replicate and further test their work, thus either confirming new explanations or refuting them.

Scientific terminology avoids confusion amongst the scientific community, enabling better understanding and testing of scientific explanations.

Candidates will be able to provide explanations using correct scientific terms, and support arguments with equations, diagrams and clear sketch graphs when appropriate. The need for answers to be expressed in such a way pervades the written papers and the ISA. Furthermore, questions requiring extended writing will be set in which marks may be reserved for demonstrating this skill.</td></tr>
<tr><td></td><td>Examples in this specification include:

• Many opportunities exist through the assessment of the written examinations at both AS and A2. Candidates will be using extended prose in many of these externally assessed units.</td></tr>
</table>

<table>
<tr><td rowspan="3">I</td><td>Consider applications and implications of science and appreciate their associated benefits and risks</td></tr>
<tr><td>Scientific advances have greatly improved the quality of life for the majority of people. Developments in technology, medicine and materials continue to further these improvements at an increasing rate.
Scientists can predict and report on some of the beneficial applications of their experimental findings.
Scientists evaluate, and report on, the risks associated with the techniques they develop and the applications of their findings.
Candidates will be able to study how science has been applied to develop technologies that improve our lives, but will also appreciate that the technologies themselves pose significant risks that have to be balanced against the benefits.</td></tr>
<tr><td>Examples in this specification include:
• Unit 2, Module 2: Energy and the Environment (Section B – Impact of energy conversion)
The exploitation of science and its application throughout the Industrial Revolution has contributed directly to global warming. Candidates should be made aware of the impact this has had on the environment and how scientists are using their current findings to inform decision-makers of the consequence of global warming and advise them how to minimise its effects.
• Unit 4, Module 3: Imaging the Invisible (Section D – Medical diagnosis without surgery)
In this section candidates should be made aware of a range of techniques which can be used in diagnosis. They should consider the benefits whilst appreciating the risks of exposure to radiation and strong magnetic fields.</td></tr>
<tr><td rowspan="3">J</td><td>Consider ethical issues in the treatment of humans, other organisms and the environment</td></tr>
<tr><td>Scientific research is funded by society, either through public funding or through private companies that obtain their income from commercial activities. Scientists have a duty to consider ethical issues associated with their findings.
Individual scientists have ethical codes that are often based on humanistic, moral and religious beliefs.
Scientists are self-regulating and contribute to decision-making about what investigations and methodologies should be permitted.
Candidates will be able to appreciate how science and society interact. They should examine how science has provided solutions to problems but recognise that the solutions require society to form judgements as to whether the solution is acceptable in view of moral issues that result. Issues such as the effects on the planet, and the economic and physical well-being of the living things on it should be considered.</td></tr>
<tr><td>Examples in this specification include:
• Unit 1, Module 1: The World of Music (Section C – Storage and playback)
Candidates should be made aware that as technology progresses the ability to reproduce music to a high standard is readily available to all. A discussion of the ethics of copyright infringement could be considered here.
• Unit 5, Module 3: Energy from the Nucleus (Section F – Perceptions of risk)
The problems of public safety and how the dangers are balanced against benefits is a theme which can be used throughout this module.</td></tr>
</table>

K	**Appreciate the role of the scientific community in validating new knowledge and ensuring integrity**
	The findings of scientists are subject to peer review before being accepted for publication in a reputable scientific journal. The interests of the organisations that fund scientific research can influence the direction of research. In some cases the validity of those claims may also be influenced. Candidates will understand that scientists need a common set of values and responsibilities. They should know that scientists undertake a peer review of the work of others. They should know that scientists work with a common aim to progress scientific knowledge and understanding in a valid way and that accurate reporting of findings takes precedence over recognition of success of an individual. Similarly, the value of findings should be based on their intrinsic value and the credibility of the research.
	Examples in this specification include: • *Unit 1, Module 2: From Quarks to Quasars (Section C – The particle picture)* In the search for a unifying theory, scientists are making new discoveries based on theoretical predications and continue to work to confirm the discovery of others. • *Unit 5, Module 3: Energy from the Nucleus (Section E – Fusion – energy for the future)* In their discussions of nuclear fusion, teachers could introduce the ideas behind cold fusion. Candidates could be made aware of the fact that scientists were unable to successfully reproduce the initial findings and subsequently the discovery of cold fusion was rejected.
L	**Appreciate the ways in which society uses science to inform decision-making**
	Scientific findings and technologies enable advances to be made that have potential benefit for humans. In practice, the scientific evidence available to decision-makers may be incomplete. Decision-makers are influenced in many ways, including by their prior beliefs, their vested interests, special interest groups, public opinion and the media, as well as by expert scientific evidence. Candidates will be able to appreciate that scientific evidence should be considered as a whole. They should realise that new scientific developments inform new technology. They should realise the media and pressure groups often select parts of scientific evidence that support a particular viewpoint and that this can influence public opinion which in turn may influence decision-makers. Consequently, decision-makers may make socially and politically acceptable decisions based on incomplete evidence.
	Examples in this specification include: • *Unit 1, Module 1: The World of Music (Section B – Analogue or digital)* Teachers could consider the effects of improved communication that digital electronics brings to society and the range of information made available to decision-makers in industry, services and government. On a wider issue teachers may wish to explore the effect of rapidly changing and quickly redundant technology on the use of material resources • *Unit 4, Module 1: Experiences Out of this World (Section B – Leaving the Earth)* This section, along with Sections A and C from this module, could be used as the basis for discussion of the technology associated with space travel and how this technology has filtered down and now has wider benefits for society. Discussions centred around the contribution of space travel to global warming could also be considered along with ways in which the technology and findings could be used for the wider benefit of humankind.

3.8 Guidance on Internal Assessment

Introduction

The GCE Sciences share a common approach to centre assessment. This is based on the belief that assessment should encourage practical activity in science, and that practical activity should encompass a broad range of activities. This section must be read in conjunction with information in the Teacher Resource Bank.

Practical and Investigative Skills are assessed in the centre assessed units, Unit 3 and Unit 6 worth, respectively, 20% of the AS award (and 10% of the Advanced Level Award) and 10% of the full Advanced level award.

There are two routes for the assessment of Practical and Investigative Skills

Either

Route T: Practical Skills Assessment (PSA) + Investigative Skills Assignment (ISA) – Teacher-marked

Or

Route X: Practical Skills Verification (PSV) + Externally Marked Practical Assignment (EMPA) – AQA-marked.

Both routes to assessment are available at AS and A2.

Centres can not make entries for the same candidate for both assessment routes [T and X] in the same examination series.

3.8.1 Centre Assessed Route T (PSA/ISA)

Each centre assessed unit comprises:

- Practical Skills Assessment (PSA)
- Investigative Skills Assignment (ISA).

The PSA consists of the centre's assessment of the candidate's ability to demonstrate practical skills throughout the course; thus, candidates should be encouraged to carry out practical and investigative work throughout the course of their study. This work should cover the skills and knowledge of *How Science Works* (Section 3.7) and in Sections 3.3 and 3.6.

The ISA has two stages where candidates:

- undertake practical work, collect and process of data
- complete a written ISA test.

Each stage must be carried out under controlled conditions but may be scheduled at a time convenient to the centre. The written test must be completed in a single, uninterrupted session.

The ISA is set externally by AQA, but internally marked, with marking guidelines provided by AQA. In a given academic year two ISAs at each of AS and A2 level will be provided.

Practical Skills Assessment (PSA)

Candidates are assessed throughout the course on practical skills, using a scale from 0-9. The mark submitted for practical skills should be judged by the teacher. Teachers may wish to use this section for formative assessment and should keep an ongoing record of each candidate's performance but the mark submitted should represent the candidate's practical abilities over the whole course. Please refer to section 3.8.3 for marking guidance and criteria.

The nature of the assessment

Since the skills in this section involve implementation they must be assessed while the candidate is carrying out practical work. Practical activities are not intended to be undertaken as formal tests and supervisors can provide the usual level of guidance that would normally be given during teaching. In order to provide appropriate opportunities to demonstrate the necessary skills, instructions provided must not be too prescriptive but should allow candidates to make decisions for themselves, particularly concerning the conduct of practical work, their organisation and the manner in which equipment is used.

The tasks

There are no specific tasks set by AQA in relation to the PSA. Centres should set up tasks in order for the candidates to be provided opportunities to use the equipment deemed appropriate at the given level. Further guidance can be provided by the Assessment Adviser attached to the centre. Details of the appropriateness of the equipment and techniques are provided in Unit 3 and Unit 6 (Section 3.3 and 3.6).

The assessment criteria

In the context of material specified in the relevant AS or A2 specification candidates will be assessed on the following skills:

- Following instructions
- Selecting and using equipment
- Organisation and safety

Detailed descriptors for these three skills are provided in Section 3.8.3.

AQA may wish to ask for further supporting evidence from centres in relation to the marks awarded for the PSA. Centres should therefore keep records of their candidates' performances in their practical activities throughout the course. (For example, a laboratory diary, log or tick sheet.)

Further guidance for awarding of marks for the PSA will be provided in the Teacher Resource Bank.

Use of ICT during PSA

Candidates are encouraged to use ICT where appropriate in the course of developing practical skills, for example in collecting and analysing data.

Investigative Skills Assignment (ISA)

The Investigative Skills Assignment carries 41 marks and has two stages.

Stage 1: Collection and Processing of data

Candidates carry out practical work following an AQA task sheet. Centres may use the task sheet, as described, or may make minor suitable modifications to materials or equipment following AQA guidelines. Any modifications made to the task sheet must be agreed in writing with the AQA Assessment Adviser. The task may be conducted in a normal timetabled lesson but must be under controlled conditions.

Candidates will be asked to collect data and represent it in a table of their own design. They will be instructed to process the data and draw an appropriate graph. The teacher must not instruct the candidates on the presentation of the data or on the choice of graph/chart. All the completed work must be handed to the teacher at the end of the session. The teacher assesses the candidates' work to AQA marking guidelines.

There is no specified time limit for this stage.

Stage 2: The ISA written test

The ISA test should be taken as soon as convenient after completion of Stage 1 and under controlled conditions. Each candidate is provided with an ISA test and the candidate's completed material from Stage 1. The teacher uses the AQA marking guidelines to assess the ISA test.

The ISA test is in two Sections:

a) Section A

This consists of a number of questions relating to the candidate's own data.

b) Section B

This section will provide a further set of data related to the original experiment. A number of questions relating to analysis and evaluation of the data then follow.

The number of marks allocated to each section may vary slightly with each ISA test.

Use of ICT during ISA

ICT may be used during the ISA Stages 1 and 2 but teachers should note any restrictions in the ISA marking guidelines. Use of the internet is not permitted.

Candidates absent for the practical work

A candidate absent for the practical work (Stage 1) should be given an opportunity to carry out the practical work before they sit the ISA test. This may be with another group or at a different time. In extreme circumstances when such arrangements are not possible, the teacher can supply a candidate with class data. In this case, candidates cannot be awarded marks for Stage 1, but can still be awarded marks for Stage 2 of the assessment.

Material from AQA

For each ISA, AQA will provide:

- Teachers' Notes
- Task sheet
- ISA written test
- Marking guidelines

When received, this material must be kept under secure conditions within the centre. If it is to be used on more than one session, then the centre must ensure security between sessions.

Further details regarding this material will be provided.

Security of assignments

All ISA materials including marked ISAs should be treated like examination papers and kept under secure conditions until the publication of results.

General Information

Route T

Administration

In any year a candidate may attempt either or both of the two ISAs.

For each candidate, the teacher should submit to AQA a total mark comprising:

- The PSA mark
- The better ISA mark (if two have been attempted).

The ISA component of this mark must come from one ISA only, i.e. the marks awarded for individual stages of different ISAs cannot be combined.

The total mark must be submitted to AQA by the due date in the academic year for which the ISA was published.

Candidates may make only one attempt at an ISA and redrafting is not permitted at any stage during the ISA.

Work to be submitted

For each candidate in the sample the following materials must be submitted to the moderator by the deadline issued by AQA:

- the candidate's data from Stage 1
- the ISA written test which includes the *Candidate Record Form*, showing the marks for the ISA and the PSA.

In addition each centre must provide:

- a *Centre Declaration Sheet*
- details of any agreed amendments to the task sheet, with information supporting the changes from the AQA Assessment Adviser.

Working in groups

For the PSA candidates may work in groups provided that any skills being assessed are the work of individual candidates. For the ISA further guidance will be provided in the Teacher Notes.

Other information

Section 6 of this specification outlines further guidance on the supervision and authentication of centre assessed units.

Section 6 also provides information in relation to the internal standardisation of marking for these units. Please note that the marking of both of the PSA and the ISA must be internally standardised (see Section 6.4).

Further support

AQA supports the centre assessed units in a number of ways:

- AQA holds annual standardising meetings on a regional basis for all internally assessed components. Section 6 of this specification provides further details about these meetings
- a Teacher Resource Bank which includes information and guidance
- Assessment Advisers are appointed by AQA to provide advice on centre assessed units. Every centre is allocated an Adviser. Details are sent to the Head of Department.

  The assessment advisers can provide guidance on:

  – issues relating to the carrying out of assignments for assessment

  – application of the marking guidelines.

Any amendments to the ISA task sheet must be discussed with the AQA Assessment Adviser and confirmation of the amendments made must be submitted to the AQA Moderator.

3.8.2 Externally Marked Route X (PSV/EMPA)

The practical and investigative skills will be assessed through:

- Practical Skills Verification (PSV) and
- Externally Marked Practical Assignment (EMPA).

The PSV requires teachers to verify their candidates' ability to demonstrate safe and skilful practical techniques and make valid and reliable observations.

The EMPA has two stages where candidates:

- Undertake a practical activity
- Complete a written EMPA test.

Each stage must be carried out under controlled conditions but may be at a time convenient to the centre. The written test must be completed in a single uninterrupted session.

The EMPA is set and marked by AQA. Only one EMPA at each of AS and will be provided in a given academic year. AQA will stipulate a period of time during which the EMPA (Tasks and written test) must be completed.

Practical Skills Verification

Candidates following this route must undertake specific practical exercises. They will be required to work individually and carry out 5 short practical exercises under supervision in the laboratory during normal class time. The exercises will be set by AQA and may be undertaken at any stage during the course at the centre's discretion either as individual exercises or by organising more than one exercise to be taken at a said time. The candidates should be supervised during the practical work. They will not be expected to spend more than 3 hours in total of laboratory time in completing these exercises. The exercises will be typical of the normal practical work that would be expected to be covered as part of any AS or A2 physics course and should not add any additional burden to centres.

The teacher will confirm on the *Candidate Record Form*, for each candidate that this requirement has been met. Failure to complete the tick box will lead to a mark of zero being awarded to the candidate for the whole of this unit. Knowledge and understanding of the skills shown in the tasks may be assessed of the EMPA written tests.

ICT

Candidates may use ICT where appropriate in the course of developing practical skills, for example in collecting and analysing data.

Externally Marked Practical Assignment (EMPA)

The Externally Marked Practical Assignment carries 55 marks and has two stages.

Stage 1: Collection and Processing of data

Candidates carry out practical work following AQA instructions. These will be laid out in Section A EMPA test answer booklet. The activity may be conducted in a normal timetabled lesson and at a time convenient to the centre. Candidates collect raw data and represent it in a table of their own design or make observations. The candidates' work must be handed to the teacher at the end of each session.

The activity will be made up of two tasks, centred around a particular area of physics. The tasks will assess the skills stipulated in the assessment objective AO3 (see section 4.2).

Centres will be guided how to set up the EMPA task by Teachers Notes which may be used, as described, or centres may make minor suitable modifications to materials or equipment following AQA guidelines. Any modifications made to the tasks must be indicated with the material sent to the examiner.

Candidates should work individually and be supervised throughout. The task will provide them with sufficient information to obtain reliable measurements which they will be required to identify, record, and process and eliminate possible anomalies and minimise measurement errors. They will be expected to then further analyse and evaluate their measurements in Stage 2. The questions in Section B of the EMPA will focus on both tasks.

There is no specified time limit for this stage.

Stage 2: The EMPA written test

The EMPA test should be taken as soon as convenient after completion of Stage 1 and under controlled conditions. Each candidate is provided with a test paper (Section B of the EMPA) and the candidate's completed material written from Stage 1.

The test will be a duration of 1 hour 15 minutes.

Candidates will be required:

- to use their results and graph from Stage 1 to perform further analysis in order to arrive at a quantifiable outcome or conclusion
- to assess elements of the practical activity, such as the overall accuracy of the outcomes

Use of ICT during the EMPA

ICT may be used during the EMPA Stages 1 and 2 but teachers should note any restrictions in the Teachers' Notes. Use of the internet is not permitted.

Candidates absent for the practical work

A candidate absent for the practical work (Stage 1) should be given an opportunity to carry out the practical work before they sit the EMPA written test. This may be with another group or at a different time. In extreme circumstances, when such arrangements are not possible, the teacher can supply a candidate with class data. This must be noted on the *Candidate Record Form*. In this case, the candidate cannot be awarded marks for Stage 1 but can still be awarded marks for Stage 2 of the assessment.

Material from AQA

For each EMPA, AQA will provide:

- Teachers' Notes
- Section A and Section B papers of the EMPA test (Stage 1 and Stage 2 documentation)

When received, this material must be kept under secure conditions. If it is to be used in more than one session, then the centre must ensure security of material between sessions. Further details regarding this material will be provided.

Security of assignments

Completed EMPAs should be treated like examination papers and kept under secure conditions until sent to the AQA examiner. All other EMPA materials should be kept under secure conditions until publication of results.

General Information

Route X

Administration

Only one EMPA will be available in any year at AS and at A2. AQA will stipulate a period of time during which the EMPA (task and test) must be completed.

Candidates may make only one attempt at a particular EMPA and redrafting is not permitted at any stage during the EMPA.

Work to be submitted

The material to be submitted to the examiner for each candidate consists of:

- the candidate's data in the Section A test papers (Stage 1 of the EMPA)
- the candidate's completed Section B test paper (Stage 2 of the EMPA) which includes the *Candidate Record Form*, including the PSV verification of the 5 practical exercises.

In addition each centre must provide:

- a *Centre Declaration Sheet*
- details of any agreed amendments to the tasks, with information supporting the changes from the Assessment Adviser.

Working in groups

For the PSV candidates may work in groups provided that any skills being assessed are the work of individual candidates. For the EMPA further guidance will be provided but the opportunity for group work will not be a common feature.

Other information

Section 6 of this specification outlines further guidance on the supervision and authentication of Internally assessed units.

Further support

AQA supports centres in a number of ways:

- A Teacher Resource Bank which includes further information and guidance
- Assessment Advisers are appointed by AQA to provide advice on internally assessed units. Every centre is allocated an Assessment Adviser.

The Assessment Advisers can provide guidance on issues relating to the carrying out of tasks for assessment.

Any amendments to the EMPA task sheet must be discussed with the AQA Assessment Adviser and confirmation of the amendments made must be submitted to the AQA Examiner.

3.8.3 General Marking Guidance for each PSA

Centres should use the following marking grids in relation to the PSA assessment.

Each skill has a descriptor with a three point scale (0, 1, 2 or 3 marks). The descriptors are hierarchical and different for Unit 3 and Unit 6 to reflect the differing demand of the Units.

Candidates should be awarded marks which reflect their level of performance over the whole course.

Unit 3		
Following instructions and group work	**Selecting and using equipment**	**Organisation and safety**
1A Follows instructions in standard procedures but sometimes needs guidance.	1B Uses standard laboratory equipment with some guidance as to the appropriate instrument/range.	1C Works in a safe and organised manner following guidance provided but needs reminders
2A Follows instructions for standard procedures without guidance. Works with others making some contribution.	2B Uses standard laboratory equipment selecting the appropriate range.	2C Works in an organised manner with due regard to safety with only occasional guidance or reminders
3A Follows instructions on complex tasks without guidance. Works with others making some contribution.	3B Selects and uses standard laboratory equipment with appropriate precision and recognises when it is appropriate to repeat measurements.	3C Works safely without supervision and guidance. (Will have effectively carried out own risk assessment.)
Total 3 marks	Total 3 marks	Total 3 marks

Unit 6		
Following instructions and group work	**Selecting and using equipment**	**Organisation and safety**
4A Plans and works with some guidance, selecting appropriate techniques and following instructions.	4B Selects and uses suitable equipment, including at least two complex instruments **or** techniques appropriate to the A2 course	4C Demonstrates safe working practices in using a range of equipment appropriate to the A2 course
5A Plans and works without guidance, selecting appropriate techniques and following instructions. Participates in group work.	5B Selects and uses suitable equipment, including more than two complex instruments **and** techniques appropriate to the A2 course.	5C Demonstrates safe working practices in some of the more complex procedures encountered on the A2 course
6A Plans and works without guidance, selecting appropriate techniques and following complex instructions. Participates in group work.	6B Selects and uses suitable equipment with due regard to precision, including a **wide** range of at least 6 complex instruments and techniques appropriate to the A2 course.	6C Consistently demonstrates safe working practices in the more complex procedures encountered on the A2 course.
Total 3 marks	Total 3 marks	Total 3 marks

3.9 Mathematical Requirements

In order to develop their skills, knowledge and understanding in science, candidates need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as set out below.

	Candidates should be able to:
Arithmetic and computation	• recognise and use expressions in decimal and standard form • use ratios, fractions and percentages • use calculators to find and use x^n, $1/x$, $\sqrt{x}$, $\log_{10}x$, e^x, $\log_e x$ • use calculators to handle sin x, cos x, tan x when x is expressed in degrees or radians.
Handling data	• use an appropriate number of significant figures • find arithmetic means • make order of magnitude calculations.
Algebra	• understand and use the symbols: $=$, $<$, $<<$, $>>$, $>$, $\propto$, $\sim$. • change the subject of an equation by manipulation of the terms, including positive, negative, integer and fractional indices • substitute numerical values into algebraic equations using appropriate units for physical quantities • solve simple algebraic equations.
Graphs	• translate information between graphical, numerical and algebraic forms • plot two variables from experimental or other data • understand that $y = mx + c$ represents a linear relationship • determine the slope and intercept of a linear graph • draw and use the slope of a tangent to a curve as a measure of rate of change • understand the possible physical significance of the area between a curve and the x -axis and be able to calculate it or measure it by counting squares as appropriate • use logarithmic plots to test exponential and power law variations • sketch simple functions including $y = k/x$, $y = kx^2$, $y = k/x^2$, $y = \sin x$, $y = \cos x$, $y = e^{-kx}$
Geometry and trigonometry	• calculate areas of triangles, circumferences and areas of circles, surface areas and volumes of rectangular blocks, cylinders and spheres • use Pythagoras' theorem, and the angle sum of a triangle • use sines, cosines and tangents in physical problems • understand the relationship between degrees and radians and translate from one to the other.

4 Scheme of Assessment

4.1 Aims

AS and A Level courses based on this specification should encourage candidates to:

a) develop their interest in, and enthusiasm for the subject, including developing an interest in further study and careers in the subject

b) appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society

c) develop and demonstrate a deeper appreciation of the skills, knowledge and understanding of *How Science Works*

d) develop essential knowledge and understanding of different areas of the subject and how they relate to each other.

4.2 Assessment Objectives (AOs)

The Assessment Objectives are common to AS and A Level. The assessment units will assess the following Assessment Objectives in the context of the content and skills set out in Section 3 (Subject Content).

These assessment objectives are the same for AS and A Level. They apply to the whole specification.

In the context of these assessment objectives, the following definitions apply:

- Knowledge: includes facts, specialist vocabulary, principles, concepts, theories, models, practical techniques, studies and methods
- Issues: include ethical, social, economic, environmental, cultural, political and technological
- Processes: include collecting evidence, explaining, theorising, modelling, validating, interpreting, planning to test an idea, peer reviewing.

AO1: Knowledge and understanding of science and of *How Science Works*

Candidates should be able to:

a) recognise, recall and show understanding of scientific knowledge

b) select, organise and communicate relevant information in a variety of forms.

AO2: Application of knowledge and understanding of science and of *How Science Works*

Candidates should be able to:

a) analyse and evaluate scientific knowledge and processes

b) apply scientific knowledge and processes to unfamiliar situations including those related to issues

c) assess the validity, reliability and credibility of scientific information.

AO3: *How Science Works* – Physics

Candidates should be able to:

a) demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods

b) make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy

c) analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

Quality of Written Communication (QWC)

In GCE specifications which require candidates to produce written material in English, candidates must:

- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

In this specification QWC will be assessed in all externally assessed units.

Weighting of Assessment Objectives for AS

The table below shows the approximate weighting of each of the Assessment Objectives in the AS units.

Assessment Objectives	Unit Weightings (%)			Overall weighting of AOs (%)
	Unit 1	Unit 2	Unit 3	
AO1	16	16	2	34
AO2	17	17	2	36
AO3	7	7	16	30
Overall weighting of units (%)	40	40	20	100

Weighting of Assessment Objectives for A Level

The table below shows the approximate weighting of each of the Assessment Objectives in the AS and A2 units.

Assessment Objectives	Unit Weightings (%)						Overall weighting of AOs (%)
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	
AO1	8	8	1	6	6	1	30
AO2	8.5	8.5	1	10.5	10.5	1	40
AO3	3.5	3.5	8	3.5	3.5	8	30
Overall weighting of units (%)	20	20	10	20	20	10	100

4.3 National Criteria

This specification complies with the following:

- The Subject Criteria for Science
- The Code of Practice for GCE
- The GCE AS and A Level Qualification Criteria
- The Arrangements for the Statutory Regulation of External Qualifications in England, Wales and Northern Ireland: Common Criteria.

4.4 Prior Learning

There are no prior learning requirements. We recommend that candidates should have acquired the skills and knowledge associated with a GCSE Science (Additional) course or equivalent.

However, any requirements set for entry to a course following this specification are at the discretion of centres.

4.5 Synoptic Assessment and Stretch and Challenge

The definition of synoptic assessment in the context of science is as follows.

Synoptic assessment requires candidates to make and use connections within and between different areas of science, for example, by:

- applying knowledge and understanding of more than one area to a particular situation or context
- using knowledge and understanding of principles and concepts in experimental and investigative work and in the analysis and evaluation of data
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

There is a requirement to formally assess synopticity at A2. Synoptic assessment in Physics Specification B is assessed in all the A2 units through both the written papers (Unit 4 and Unit 5) and the Investigative and Practical Skills Unit (Unit 6).

The requirement that Stretch and Challenge is included at A2 will be met in the externally assessed units by:

- using a variety of stems in questions to avoid a formulaic approach through the use of such words as: analyse, evaluate, compare, discuss
- avoiding assessments being too atomistic, connections between areas of content being used where possible and appropriate
- having some requirement for extended writing
- using a range of question types to address different skills i.e. not just short answer/structured questions
- asking candidates to bring to bear knowledge and the other prescribed skills in answering questions rather than simply demonstrating a range of content coverage.

4.6 Access to Assessment for Disabled Students

AS/A Levels often require assessment of a broader range of competences. This is because they are general qualifications and, as such, prepare candidates for a wide range of occupations and higher level courses.

The revised AS/A Level qualification and subject criteria were reviewed to identify whether any of the competences required by the subject presented a potential barrier to any disabled candidates. If this were the case, the situation was reviewed again to ensure that such competences were included only where essential to the subject. The findings of this process were discussed with disability groups and with disabled people.

Reasonable adjustments are made for disabled candidates in order to enable them to access the assessments. For this reason, very few candidates will have a complete barrier to any part of the assessment.

Candidates who are still unable to access a significant part of the assessment, even after exploring all possibilities through reasonable adjustments, may still be able to receive an award. They would be given a grade on the parts of the assessment they have taken and there would be an indication on their certificate that not all the competences had been addressed. This will be kept under review and may be amended in the future.

5 Administration

5.1 Availability of Assessment Units and Certification

Examinations and certification for this specification are available as follows:

	Availability of units		Availability of certification	
	AS	A2	AS	A Level
January 2010	1, 2	4, 5	✔	
June 2010	1, 2, 3	4, 5, 6	✔	✔
January 2011 onwards	1, 2	4, 5	✔	✔
June 2011 onwards	1, 2, 3	4, 5, 6	✔	✔

5.2 Entries

Please refer to the current version of *Entry Procedures and Codes* for up-to-date entry procedures. You should use the following entry codes for the units and for certification.

Unit 1 – PHYB1

Unit 2 – PHYB2

Unit 3 – **either** PHB3T **or** PHB3X

Unit 4 – PHYB4

Unit 5 – PHYB5

Unit 6 – **either** PHB6T **or** PHB6X

Centres can not make entries for the same candidate for both assessment routes [T and X] in either Unit 3 or Unit 6 in the same examination series.

AS certification – 1456

A Level certification – 2456

5.3 Private Candidates

This specification is available to private candidates under certain conditions. Because of the nature of the assessment of the practical skills, candidates must be attending an AQA centre which will supervise and assess the work. Private candidates should write to AQA for a copy of *Supplementary Guidance for Private Candidates.*

Entries from private candidates can only be accepted where the candidate is registered with an AQA registered centre that will accept responsibility for:

- supervising the practical components of the PSA/ISA or PSV/EMPA
- supervising the written component of the ISA or EMPA
- prime marking the centre assessed work.

Candidates wishing to repeat or complete the AS and/or A2 components may only register as private candidates if they already have a previously moderated mark for Units 3 and 6, respectively, or if they can find a centre that will comply with the above requirements.

5.4 Access Arrangements and Special Consideration

We have taken note of equality and discrimination legislation and the interests of minority groups in developing and administering this specification.

We follow the guidelines in the Joint Council for Qualifications (JCQ) document: *Access Arrangements, Reasonable Adjustments and Special Consideration: General and Vocational Qualifications.* This is published on the JCQ website (**http://www.jcq.org.uk**) or you can follow the link from our website (**http://www.aqa.org.uk**).

Section 8.4 of the above JCQ document states that "a practical assistant is not permitted to carry out tasks which are the focus of the assessment". Accordingly, only candidates who can carry out the tasks themselves can access marks for the Practical Skills Assessment (PSA) in Unit 3 and Unit 6.

However, so that candidates may obtain experimental results that can be used in the Investigative Skills Assignment (ISA), practical assistants may be used to carry out the manipulation under the candidate's instructions. In these circumstances, as stated in section 2.4 of the JCQ document, marks cannot be gained for demonstrating techniques. The candidates will be able to access the marks available for the other skills, for example handling and evaluating data collected, and drawing conclusions in AO3.

The use of word processors will not be allowed for drawing graphs for the Investigative Skills Assignment (ISA) element of the Centre Assessed Units and thus only candidates who can draw the graph by hand will be able to access the marks available.

Access Arrangements

We can make arrangements so that candidates with disabilities can access the assessment. These arrangements must be made **before** the examination. For example, we can produce a Braille paper for a candidate with a visual impairment.

Special Consideration

We can give special consideration to candidates who have had a temporary illness, injury or indisposition at the time of the examination. Where we do this, it is given **after** the examination.

Applications for access arrangements and special consideration should be submitted to AQA by the Examinations Officer at the centre.

5.5 Language of Examinations

We will provide units in English only.

5.6 Qualification Titles

Qualifications based on this specification are:

- AQA Advanced Subsidiary GCE in Physics B: Physics in Context, and
- AQA Advanced Level GCE in Physics B: Physics in Context.

5.7 Awarding Grades and Reporting Results

The AS qualification will be graded on a five-point grade scale: A, B, C, D and E. The full A Level qualification will be graded on a six-point scale: A*, A, B, C, D and E. To be awarded an A*, candidates will need to achieve a grade A on the full A Level qualification and an A* on the aggregate of the A2 units.

For AS and A Level, candidates who fail to reach the minimum standard for grade E will be recorded as U (unclassified) and will not receive a qualification certificate. Individual assessment unit results will be certificated.

5.8 Re-sits and Shelf-life of Unit Results

Unit results remain available to count towards certification, whether or not they have already been used, as long as the specification is still valid.

Candidates may re-sit a unit any number of times within the shelf-life of the specification. The best result for each unit will count towards the final qualification. Candidates who wish to repeat a qualification may do so by re-taking one or more units. The appropriate subject award entry, as well as the unit entry/entries, must be submitted in order to be awarded a new subject grade.

Candidates will be graded on the basis of the work submitted for assessment.

6 Administration of Internally Assessed Units: Route T and Route X

The Head of Centre is responsible to AQA for ensuring that Internally Assessed work is conducted in accordance with AQA's instructions and JCQ instructions.

Centres can not make entries for the same candidate for both assessment routes [T and X] in either Unit 3 or Unit 6 in the same examination series.

6.1 Supervision and Authentication of the Centre Assessed Units

The Code of Practice for GCE requires:

- **candidates to** sign the Candidate Record Form (CRF) to confirm that the work submitted is their own, and
- **teachers/assessors** to confirm on the CRF that the work submitted is solely that of the candidate concerned and was conducted under the conditions laid down by the specification.

The completed CRF for each candidate must be attached to his/her work. Failure to sign the authentication statement may delay the processing of the candidates' results.

In all cases, direct supervision is necessary to ensure that the work submitted can be confidently authenticated as the candidate's own.

If teachers/assessors have reservations about signing the authentication statements, the following points of guidance should be followed.

- If it is believed that a candidate has received additional assistance and this is acceptable within the guidelines for the relevant specification, the teacher/assessor should award a mark which represents the candidate's unaided achievement. The authentication statement should be signed and information given on the relevant form.
- If the teacher/assessor is unable to sign the authentication statement for a particular candidate, then the candidate's work cannot be accepted for assessment.
- If malpractice is suspected, the Examinations Officer should be consulted about the procedure to be followed.

Route T

All teachers who have assessed the work of any candidate entered for each unit must sign the declaration of authentication.

The practical work for the PSA and for the ISA should be carried out in normal lesson time with a degree of supervision appropriate for candidates working in a laboratory. The processing of raw data and the ISA written test should be taken in normal lesson time under controlled conditions.

Redrafting of answers to any stage of the ISA is not permitted. Candidates must **not** take their work away from the laboratory.

Material to submit to moderator
For each candidate in the sample, the following material must be submitted to the moderator by the deadline issued by AQA:

- the candidate's data from Stage 1
- the ISA written test which includes the *Candidate Record Form,* showing the marks for the ISA and the PSA.

In addition each centre must provide:

- a *Centre Declaration Sheet*
- details of any amendments to the task sheet with the information supporting the changes from the Assessment Adviser, if there are any significant changes

Route X

The practical work for the PSV and Stage 1 of the EMPA should be carried out in normal lesson time with a degree of supervision appropriate for candidates working in a laboratory. The processing of raw data and the EMPA written test should be taken in normal lesson time under controlled conditions.

Redrafting of answers to any stage of the EMPA is not permitted. Candidates must **not** take their work away from the class.

Material to submit to examiner
For each candidate, the following material must be submitted to the examiner by the deadline issued by AQA:

- the candidate's data from Stage 1 Section A (Task 1 and Task 2)
- the EMPA written test (Section B) which includes the *Candidate Record Form,* including the PSV verification of safe and skilful practical techniques and reliable and valid observations.

In addition each centre must provide:

- a *Centre Declaration Sheet*
- details of any amendments to the task sheet with the information supporting the changes from the Assessment Adviser, if there are any significant changes.

6.2 Malpractice

Teachers should inform candidates of the AQA Regulations concerning malpractice.

Candidates must **not**:

- submit work which is not their own
- lend work to other candidates
- submit work typed or word-processed by a third person without acknowledgement.

These actions constitute malpractice, for which a penalty (e.g. disqualification from the examination) will be applied.

Route T

Where suspected malpractice in centre assessed work is identified by a centre after the candidate has signed the declaration of authentication, the Head of Centre must submit full details of the case to AQA at the earliest opportunity. The form JCQ/M1 should be used. Copies of the form can be found on the JCQ website (http://www.jcq.org.uk/).

Malpractice in centre assessed work discovered prior to the candidate signing the declaration of authentication need not be reported to AQA, but should be dealt with in accordance with the centre's internal procedures. AQA would expect centres to treat such cases very seriously. Details of any work which is not the candidate's own must be recorded on the *Candidate Record Form* or other appropriate place.

Route X

If the teacher administering the EMPA believes that a student is involved in malpractice, he/she should contact AQA.

If the examiner suspects malpractice with the EMPA, at any stage, he/she will raise the matter with the Irregularities Office at AQA. An investigation will be undertaken, in line with the JCQ's policies on Suspected Malpractice in Examinations and Assessments.

6.3 Teacher Standardisation (Route T only)

We will hold annual standardising meetings for teachers, usually in the autumn term, for the centre assessed units. At these meetings we will provide support in developing appropriate coursework tasks and using the marking criteria.

If your centre is new to this specification, you must send a representative to one of the meetings. If you have told us you are a new centre, either by submitting an estimate of entry or by contacting the subject team, we will contact you to invite you to a meeting.

We will also contact centres if:

- the moderation of coursework from the previous year has identified a serious misinterpretation of the coursework requirements
- inappropriate tasks have been set, or
- a significant adjustment has been made to a centre's marks.

In these cases, centres will be expected to send a representative to one of the meetings. For all other centres, attendance is optional. If you are unable to attend and would like a copy of the materials used at the meeting, please contact the subject team at **physics-gce@aqa.org.uk**.

6.4 Internal Standardisation of Marking (Route T only)

Centres must standardise marking within the centre to make sure that all candidates at the centre have been marked to the same standard. One person must be responsible for internal standardisation. This person should sign the *Centre Declaration Sheet* to confirm that internal standardisation has taken place.

Internal standardisation involves:

- all teachers marking some trial pieces of work and identifying differences in marking standards
- discussing any differences in marking at a training meeting for all teachers involved in the assessment
- referring to reference and archive material such as previous work or examples from AQA's teacher standardising meetings.

6.5 Annotation of Centre Assessed Work (Route T only)

The Code of Practice for GCE states that the awarding body must require internal assessors to show clearly how the marks have been awarded in relation to the marking criteria defined in the specification and that the awarding body must provide guidance on how this is to be done.

The annotation will help the moderator to see as precisely as possible where the teacher considers that the candidates have met the criteria in the specification.

Work could be annotated by the following method:

- key pieces of evidence flagged throughout the work by annotation either in the margin or in the text
- summative comments on the work, referencing precise sections in the work.

6.6 Submitting Marks and Sample Work for Moderation (Route T only)

The total mark for each candidate must be submitted to AQA and the moderator on the mark forms provided or by Electronic Data Interchange (EDI) by the specified date. Centres will be informed which candidates' work is required in the samples to be submitted to the moderator.

6.7 Factors Affecting Individual Candidates

Teachers should be able to accommodate the occasional absence of candidates by ensuring that the opportunity is given for them to make up missed assessments.

If work is lost, AQA should be notified immediately of the date of the loss, how it occurred, and who was responsible for the loss. Centres should use the JCQ form JCQ/LCW to inform AQA Candidate Services of the circumstances.

Where special help which goes beyond normal learning support is given, AQA must be informed through comments on the CRF so that such help can be taken into account when moderation takes place (see Section 6.1).

Candidates who move from one centre to another during the course sometimes present a problem for a scheme of internal assessment. Possible courses of action depend on the stage at which the move takes place. If the move occurs early in the course the new centre should take responsibility for assessment. If it occurs late in the course it may be possible to arrange for the moderator to assess the work through the 'Educated Elsewhere' procedure. Centres should contact AQA at the earliest possible stage for advice about appropriate arrangements in individual cases.

6.8 Retaining Evidence and Re-using Marks (Route T only)

The centre must retain the work of all candidates, with CRFs attached, under secure conditions, from the time it is assessed, to allow for the possibility of an enquiry about results. The work may be returned to candidates after the deadline for enquiries about results. If an enquiry about a result has been made, the work must remain under secure conditions in case it is required by AQA.

7 Moderation (Route T only)

7.1 Moderation Procedures

Moderation of the centre assessed work is by inspection of a sample of candidates' work, sent by post or electronically from the centre to a moderator appointed by AQA. The centre marks must be submitted to AQA and to the moderator by the specified deadline **(http://www.aqa.org.uk/deadlines.php)**. We will let centres know which candidates' work will be required in the sample to be submitted for moderation.

Following the re-marking of the sample work, the moderator's marks are compared with the centre marks to determine whether any adjustment is needed in order to bring the centre's assessments into line with standards generally. In some cases it may be necessary for the moderator to call for the work of other candidates in the centre. In order to meet this possible request, centres must retain under secure conditions and have available the centre assessed work and the CRF of every candidate entered for the examination and be prepared to submit it on demand. Mark adjustments will normally preserve the centre's order of merit but, where major discrepancies are found, we reserve the right to alter the order of merit.

7.2 Post-moderation Procedures

On publication of the AS/A Level results, we will provide centres with details of the final marks for the centre assessed unit.

The candidates' work will be returned to the centre after moderation has taken place. The centre will receive a report with, or soon after, the despatch of published results, giving feedback on the appropriateness of the tasks set, the accuracy of the assessments made, and the reasons for any adjustments to the marks.

We reserve the right to retain some candidates' work for archive or standardising purposes.

Appendices

A Performance Descriptions

These performance descriptions show the level of attainment characteristic of the grade boundaries at A Level. They give a general indication of the required learning outcomes at the A/B and E/U boundaries at AS and A2. The descriptions should be interpreted in relation to the content outlined in the specification; they are not designed to define that content.

The grade awarded will depend in practice upon the extent to which the candidate has met the Assessment Objectives (see Section 4) overall. Shortcomings in some aspects of the examination may be balanced by better performances in others.

AS Performance Descriptions for Physics

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
Assessment Objectives	**Knowledge and understanding of science and of *How Science Works*** Candidates should be able to: • recognise, recall and show understanding of scientific knowledge • select, organise and communicate relevant information in a variety of forms.	**Application of knowledge and understanding of science and of *How Science Works*** Candidates should be able to: • analyse and evaluate scientific knowledge and processes • apply scientific knowledge and processes to unfamiliar situations including those related to issues • assess the validity, reliability and credibility of scientific information.	***How Science Works*** Candidates should be able to: • demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods • make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy • analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.
A/B boundary performance descriptions	Candidates characteristically: a) demonstrate knowledge of most principles, concepts and facts from the AS specification b) show understanding of most principles, concepts and facts from the AS specification c) select relevant information from the AS specification d) organise and present information clearly in appropriate forms using scientific terminology.	Candidates characteristically: a) apply principles and concepts in familiar and new contexts involving only a few steps in the argument b) describe significant trends and patterns shown by data presented in tabular or graphical form and interpret phenomena with few errors and present arguments and evaluations clearly c) explain and interpret phenomena with few errors and present arguments and evaluations clearly d) carry out structured calculations with few errors and demonstrate good understanding of the underlying relationships between physical quantities.	Candidates characteristically: a) devise and plan experimental and investigative activities, selecting appropriate techniques b) demonstrate safe and skilful practical techniques c) make observations and measurements with appropriate precision and record these methodically d) interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.
E/U boundary performance descriptions	Candidates characteristically: a) demonstrate knowledge of some principles and facts from the AS specification b) show understanding of some principles and facts from the AS specification c) select some relevant information from the AS specification d) present information using basic terminology from the AS specification.	Candidates characteristically: a) apply a given principle to material presented in familiar or closely related contexts involving only a few steps in the argument b) describe some trends or patterns shown by data presented in tabular or graphical form c) provide basic explanations and interpretations of some phenomena, presenting very limited evaluations d) carry out some steps within calculations.	Candidates characteristically: a) devise and plan some aspects of experimental and investigative activities b) demonstrate safe practical techniques c) make observations and measurements, and record them d) interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 Performance Descriptions for Physics

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
Assessment Objectives	**Knowledge and understanding of science and of *How Science Works*** Candidates should be able to: • recognise, recall and show understanding of scientific knowledge • select, organise and communicate relevant information in a variety of forms.	**Application of knowledge and understanding of science and of *How Science Works*** Candidates should be able to: • analyse and evaluate scientific knowledge and processes • apply scientific knowledge and processes to unfamiliar situations including those related to issues • assess the validity, reliability and credibility of scientific information.	***How Science Works*** Candidates should be able to: • demonstrate and describe ethical, safe and skilful practical techniques and processes, selecting appropriate qualitative and quantitative methods • make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy • analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.
A/B boundary performance descriptions	Candidates characteristically: a) demonstrate detailed knowledge of most principles, concepts and facts from the A2 specification b) show understanding of most principles, concepts and facts from the A2 specification c) select relevant information from the A2 specification d) organise and present information clearly in appropriate forms using scientific terminology.	Candidates characteristically: a) apply principles and concepts in familiar and new contexts involving several steps in the argument b) describe significant trends and patterns shown by complex data presented in tabular or graphical form, interpret phenomena with few errors, and present arguments and evaluations clearly and logically c) explain and interpret phenomena effectively, presenting arguments and evaluations d) carry out extended calculations, with little or no guidance, and demonstrate good understanding of the underlying relationships between physical quantities. e) select a wide range of facts, principles and concepts from both AS and A2 specifications f) link together appropriate facts, principles and concepts from different areas of the specification.	Candidates characteristically: a) devise and plan experimental and investigative activities, selecting appropriate techniques b) demonstrate safe and skilful practical techniques c) make observations and measurements with appropriate precision and record these methodically d) interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

A

	Assessment Objective 1	Assessment Objective 2	Assessment Objective 3
E/U boundary performance descriptions	Candidates characteristically: a) demonstrate knowledge of some principles and facts from the A2 specification b) show understanding of some principles and facts from the A2 specification c) select some relevant information from the A2 specification d) present information using basic terminology from the A2 specification.	Candidates characteristically: a) apply given principles or concepts in familiar and new contexts involving a few steps in the argument b) describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form c) provide basic explanations and interpretations of some phenomena, presenting very limited arguments and evaluations d) carry out routine calculations, where guidance is given e) select some facts, principles and concepts from both AS and A2 specifications f) put together some facts, principles and concepts from different areas of the specification.	Candidates characteristically: a) devise and plan some aspects of experimental and investigative activities b) demonstrate safe practical techniques c) make observations and measurements, and record them d) interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

B Spiritual, Moral, Ethical, Social and other Issues

Moral, Ethical, Social and Cultural Issues

It is clear that Physics plays a major part in the development of the modern world. This specification is keenly aware of the implications of this development. The general philosophy of the subject is rooted in *How Science Works* (see Section 3.7). This section of the specification makes full references to the moral, ethical, social and cultural issues that permeate Physics and science in general at this level.

European Dimension

AQA has taken account of the 1988 Resolution of the Council of the European Community in preparing this specification and associated specimen units. The specification is designed to improve candidates' knowledge and understanding of the international debates surrounding developments in Physics and to foster responsible attitudes towards them.

Environmental Education

AQA has taken account of the 1988 Resolution of the Council of the European Community and the Report "Environmental Responsibility: An Agenda for Further and Higher Education" 1993 in preparing this specification and associated specimen units. The study of Physics as described in this specification can encourage a responsible attitude towards the environment.

Avoidance of Bias

AQA has taken great care in the preparation of this specification and specimen units to avoid bias of any kind.

Health and Safety

AQA recognises the need for safe practice in laboratories and tries to ensure that experimental work required for this specification and associated practical work complies with up-to-date safety recommendations.

Nevertheless, centres are primarily responsible for the safety of candidates and teachers should carry out their own risk assessment.

Candidates should make every effort to make themselves aware of any safety hazards involved in their work. As part of their coursework they will be expected to undertake risk assessments to ensure the safety of themselves, associated workers, the components and test equipment.

C Overlaps with other Qualifications

The AQA GCE Physics Specification B: Physics in Context overlaps with many of the Science specifications. The nature of Physics and Electronics means that there are significant overlaps with the AS content in Unit 1 and 2 and the AQA GCE Electronics. There is more marginal overlap with GCE specifications in Chemistry and Biology, as well as AQA GCE Science in Society and Environmental Studies.

The overlap with GCE Mathematics rests only on the use and application of the formulae and equations given in Section 3.9.

D Key Skills – Teaching, Developing and Providing Opportunities for Generating Evidence

Introduction

The Key Skills Qualification requires candidates to demonstrate levels of achievement in the Key Skills of Communication, Application of Number and Information Technology.

The units for the 'wider' Key Skills of Improving own Learning and Performance, Working with Others and Problem Solving are also available. The acquisition and demonstration of ability in these 'wider' Key Skills is deemed highly desirable for all candidates, but they do not form part of the Key Skills Qualification.

The units for each Key Skill comprise three sections:

- What you need to know
- What you must do
- Guidance.

Candidates following a course of study based on this specification for Physics can be offered opportunities to develop and generate evidence of attainment in aspects of the Key Skills of:

- Communication
- Application of Number
- Information Technology
- Working with Others
- Improving own Learning and Performance
- Problem Solving.

Areas of study and learning that can be used to encourage the acquisition and use of Key Skills, and to provide opportunities to generate evidence for Part B of the units, are signposted on the next page.

The above information is given in the context of the knowledge that Key Skills at level 3 will be available until 2010 with last certification in 2012.

Key Skills Qualifications of Communication, Application of Number and Information and Communication Technology will be phased out and replaced by Functional Skills qualifications in English, Mathematics and ICT from September 2010 onwards. For further information see the AQA website: **http://web.aqa.org.uk/qual/keyskills/com04.php.**

Key Skills Opportunities in Physics B

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Communication						
C3.1a	✔	✔	✔	✔	✔	✔
C3.1b	✔	✔	✔	✔	✔	✔
C3.2	✔	✔	✔	✔	✔	✔
C3.3	✔	✔	✔	✔	✔	✔
Application of Number						
N3.1	✔	✔	✔	✔	✔	✔
N3.2	✔	✔	✔	✔	✔	✔
N3.3	✔	✔	✔	✔	✔	✔
Information Technology						
ICT3.1	✔	✔	✔	✔	✔	✔
ICT3.2	✔	✔	✔	✔	✔	✔
ICT3.3			✔			✔
Working With Others						
WO3.1			✔			✔
WO3.2			✔			✔
WO3.3			✔			✔
Improving Own Learning and Performance						
LP3.1			✔			✔
LP3.2			✔			✔
LP3.3			✔			✔
Problem Solving						
PS3.1			✔			✔
PS3.2			✔			✔
PS3.3			✔			✔

E Data and Formulae Booklet

GCE Physics Specification B
Physics in Context
Data and Formula Booklet

FUNDAMENTAL CONSTANTS AND OTHER NUMERICAL DATA

Quantity	*Symbol*	*Value*	*Units*
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\ s^{-1}}$
Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\mathrm{N\ m^{2}\ kg^{-2}}$
gravitational field strength	g	9.81	$\mathrm{N\ kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\ s^{-2}}$
electron rest mass	m_e	9.11×10^{-31}	kg
	m_e	5.5×10^{-4} u	
electron charge	e	-1.60×10^{-19}	C
proton rest mass	m_p	$1.67(3) \times 10^{-27}$	kg
	m_p	1.00728 u	
neutron rest mass	m_n	$1.67(5) \times 10^{-27}$	kg
	m_n	1.00867 u	
permittivity of free space	ε_o	8.85×10^{-12}	$\mathrm{F\ m^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\ K^{-1}\ mol^{-1}}$
Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\ K^{-1}}$
Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
Wien constant	α	2.90×10^{-3}	m K

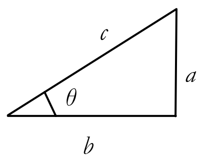
Particle Properties

Properties of quarks *antiquarks have opposite signs*

type	*charge*	*Baryon number*	*strangeness*
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	−1

GEOMETRICAL EQUATIONS

arc length	$r\theta$
circumference of circle	$2\pi r$
area of circle	πr^2
surface area of sphere	$4\pi r^2$
volume of sphere	$\frac{4}{3}\pi r^3$
surface area of cylinder	$2\pi rh$
volume of cylinder	$\pi r^2 h$



$$\sin\theta = \frac{a}{c}$$

$$\cos\theta = \frac{b}{c}$$

$$\tan\theta = \frac{a}{b}$$

$$c^2 = a^2 + b^2$$

Unit Conversions

1 atomic mass unit (u)	1.661×10^{-27} kg
1 year (y)	3.15×10^{7} s
1 parsec (pc)	3.08×10^{16} m
1 parsec	3.26 ly
1 light year (ly)	9.46×10^{15} m

Properties of Leptons

	Lepton Number
particles: $e^-, \nu_e; \mu^-, \nu_\mu; \tau^-, \nu_\tau$	**+1**
antiparticles: $e^+, \overline{\nu_e}; \mu^+, \overline{\nu_\mu}; \tau^+, \overline{\nu_\tau}$	**−1**

E

AS FORMULAE

Waves

wave speed	$c = f\lambda$
period	$T = \frac{1}{f}$
intensity	$I = \frac{P}{A}$
stretched string frequency	$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$
beat frequency	$f = f_1 - f_2$
fringe spacing	$w = \frac{\lambda D}{s}$
diffraction grating	$n\lambda = d \sin\theta$
half beam width	$\sin\theta = \frac{\lambda}{a}$
refractive index of a substance(s)	$n = \frac{c}{c_s}$
for two different substances of refractive indices n_1 and n_2	$n_1 \sin i_1 = n_2 \sin i_2$
critical angle	$\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

Mechanics

speed or velocity	$v = \frac{\Delta s}{\Delta t}$
acceleration	$a = \frac{\Delta v}{\Delta t}$
equations of motion	$v = u + at$
	$s = \frac{(u+v)}{2}t$
	$v^2 = u^2 + 2as$
	$s = ut + \frac{1}{2}at^2$
force	$F = ma$
change in potential energy	$\Delta E_p = mg\Delta h$
kinetic energy	$E_k = \frac{1}{2}mv^2$
momentum	$p = mv$
impulse	$F\Delta t = \Delta(mv)$
spring stiffness	$k = \frac{F}{\Delta L}$
energy stored for $F \propto \Delta L$	$E = \frac{1}{2}F\Delta L$
work done	$W = Fs\cos\theta$
power	$P = \frac{\Delta W}{\Delta t} = Fv$
density	$\rho = \frac{m}{V}$

Quantum Physics and Astrophysics

photon energy	$E = hf$
Einstein equation	$hf = \phi + E_{k(max)}$
line spectrum equation	$hf = E_1 - E_2$
de Broglie wavelength	$\lambda = \frac{h}{p} = \frac{h}{mv}$
Doppler shift for $v << c$	$\frac{\Delta f}{f} = -\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
Wein's law	$\lambda_{max}T = 0.0029\ \text{m K}$
Hubble law	$v = Hd$
intensity for a point source	$I = \frac{P}{4\pi r^2}$

Electricity

current	$I = \frac{\Delta Q}{\Delta t}$
electromotive force (emf)	$\varepsilon = \frac{E}{Q}$
	$\varepsilon = I(R+r)$
resistance	$R = \frac{V}{I}$
resistors in series	$R = R_1 + R_2 + R_3 + \ldots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$
resistivity	$\rho = \frac{RA}{L}$
power	$P = VI = I^2R = \frac{V^2}{R}$
potential divider formula	$V_o = \left(\frac{R_1}{R_1 + R_2}\right) \times V_i$
energy	$E = VIt$
efficiency	$= \frac{\text{useful output power}}{\text{input power}}$

Energy production and transmission

rate of heat transfer by conduction	$= UA\,\Delta\theta$
maximum power for a wind turbine	$= \frac{1}{2}\pi r^2 \rho v^3$

E

A2 FORMULAE

Gravitational fields and Mechanics

gravitational force	$F = \frac{GMm}{r^2}$
gravitational field strength	$g = \frac{F}{m}$
magnitude of field strength	$g = \frac{GM}{r^2}$
for point masses	$\Delta E_p = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$
potential	$V = -\frac{GM}{r}$
rocket equation	$v_f = v_e \ln\left(\frac{m_0}{m_f}\right)$
escape velocity	$v_{esc} = \sqrt{\frac{2GM}{R}}$
Stokes' law	$F = 6\pi\eta\sigma v_t$

Electric fields

field strength for uniform field	$E = \frac{V}{d}$
force on a charge	$F = EQ$
field strength for radial field	$F = \frac{Q}{4\pi\varepsilon_0 r^2}$
for point charges	$F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
electron gun equation	$eV = \frac{1}{2}mv^2$

Magnetic Fields

force on current – carrying conductor	$F = BIl$
force on moving charge	$F = BQv$
magnetic flux	$\Phi = BA$
magnetic flux linkage	$N\Phi = BAN$
Magnitude of induced emf	$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$

Capacitors

capacitance	$C = \frac{Q}{V}$
energy stored	$E = \frac{1}{2}QV$
decay of charge	$Q = Q_0 e^{-t/RC}$
time constant	RC
time to halve	$RC \ln 2$

Relativity

mass increase	$m = \frac{m_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$
time dilation	$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$
length contraction	$l = l_0\sqrt{\left(1 - \frac{v^2}{c^2}\right)}$

Circular Motion

angular velocity	$\omega = \frac{v}{r}$
angular acceleration	$a = \frac{\Delta\omega}{\Delta t}$
angular frequency	$\omega = 2\pi f$
centripetal force	$F = \frac{mv^2}{r} = m\omega^2 r$
centripetal acceleration	$a = \frac{v^2}{r} = r\omega^2$
angular momentum	$L = I\omega$
angular kinetic energy	$E_k = \frac{1}{2} I\omega^2$
moment of inertia	$I = \frac{T}{\alpha}$
torque	$T = F\,d$
equations of angular motion	$\omega_2 = \omega_1 + \alpha t$
	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$
	$\theta = \frac{(\omega_1 + \omega_2)}{2} t$
	$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$
power	$P = T\omega$

Gases and Thermal Physics

pressure	$p = \frac{F}{A}$
gas law (N is number of atoms)	$pV = NkT$
gas law (n is quantity in mol)	$pV = nRT$
kinetic theory model	$pV = \frac{1}{3} Nm\langle c^2 \rangle$
kinetic energy of gas molecule	$\frac{1}{2} m \langle c^2 \rangle^2 = \frac{3}{2} kT$
energy to change temperature	$Q = mc\Delta\theta$
first law of thermodynamics	$\Delta U = Q + W$ W = work done **on** the system
entropy change	$\Delta S = \frac{Q}{T}$
maximum thermal efficiency	$\eta = \frac{T_H - T_C}{T_H}$
work done	$W = p\Delta V$

Oscillations

acceleration	$a = -(2\pi f)^2 x$
displacement	$x = A\cos(2\pi f t)$
maximum speed	$v_{max} = 2\pi f A$
maximum acceleration	$a_{max} = (2\pi f)^2 A$
for a mass-spring system	$T = 2\pi\sqrt{\frac{m}{k}}$
for a simple pendulum	$T = 2\pi\sqrt{\frac{l}{g}}$

Radioactivity and nuclear physics

absorption of radiation	$I = I_0 e^{-\mu x}$
radioactive decay	$N = N_0 e^{-\lambda t}$
half-life	$T_{½} = \frac{\ln 2}{\lambda}$
radioactive change represented by	$dN/dt = -\lambda N$
activity	$A = \lambda N$
mass-energy equivalence	$\Delta E = \Delta m\, c^2$

E

GCE Physics B: Physics in Context (2455) 2009 onwards

Qualification Accreditation Number: AS 500/2572/7 - A Level 500/2570/3

To obtain free specification updates and support material or to ask us a question register with Ask AQA:
www.aqa.org.uk/ask-aqa/register

Support meetings are available throughout the life of the specification.
Further information is available at:
http://events.aqa.org.uk/ebooking